INVESTIGATION IN TO MECHANICAL AND TRIBOLOGICAL BEHAVIOUR OF ORANGE PEEL REINFORCED EPOXY COMPOSITE

A Thesis Submitted in Partial Fulfillment of the Requirements for the

Award of the Degree of

Master of Technology
In
Mechanical Engineering

(Machine Design & Analysis)

By

Prajapati Nayak
Roll No.213ME1381

NATIONAL INSTITUTE OF TECHNOLOGY ROURKELA

राष्ट्रीय प्रौधोगिकी संस्थान राउरकेला

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Prof. Samir Kumar Acharya

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Certificate

This is to certify that the thesis entitled, "**Investigation in to Mechanical and Tribological behaviour of orange peel reinforced epoxy composite**" submitted by Mr**. Prajapati Nayak** to National Institute of Technology Rourkela, during the academic session 2013-2015 is a record of bonafide research work carried out by him under my supervision and is worthy of consideration for the award of the degree of Masters of Technology in Mechanical Engineering with specialization in **Machine Design and Analysis.** The embodiment of this thesis has not been submitted to any Other University and/or Institute for the award of any degree or diploma.

Date: 26th May, 2015

Prof. Samir Kumar Acharya

Dept. of Mechanical Engineering

National Institute of Technology

Rourkela-769008

ACKNOWLEDGEMENT

It gives me immense pleasure to express my deep sense of gratitude to my supervisor **Prof. Samir Kumar Acharya** for his invaluable guidance, motivation, constant inspiration and above all for his ever co-operating attitude that enabled me in bringing up this thesis in the present form.

I would like to thanks my classmates and research scholars of Tribology lab for giving me support and for valuable suggestion during the research work. I am greatly thankful to all the staff members of the department and all my well-wishers, for their inspiration and help.

I express my deep gratitude to my organization Apex Institute of Technology and Management for permitting me to pursue this M.Tech programme. My special thanks go to my Director Sir and to Prof.Arun Padhy who are source of inspiration from the beginning of the journey to the end.

I would like to thanks my parents, brother and sister and to friend for their unconditional support, love and affection. Their encouragement and never ending kindness made everything easier to achieve.

Date: 26 $^{\mathbf{th}}$May, 2015 **Prajapati Nayak**

ABSTRACT

Over the last century, polymers have emerged as one of the most indispensable components used in everyday life, epoxy or poly-epoxide being one such example. Until recently, synthetic filler materials have been the preferred choice for reinforcement of epoxy to improve its mechanical and tribological properties. However, natural fibers are emerging as suitable alternatives to synthetic materials for obvious reasons. Several research efforts have been put to study the effectiveness of natural fiber-based materials on the mechanical behaviour of epoxy composites, focusing mainly on fibers and their weight percent within the composites. In the present work, an attempt has been made to prepare and characterize orange peel (particulate) reinforced epoxy composite for the tribological application. Composites are having 10, 20 and 30% weight fraction of orange peel were made using hand layup method and were tested on a standard pin on disc wear tester. All the test have been carried out according to the ASTM standards.

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Chapter-1

INTRODUCTION

1.1 Background and Motivation:

The human potential and intelligence is noticeable by its knowledge on the materials and technology. The works on the materials start from the early age, which leads from Copper to Aluminium and Alloy ages which is the improvement in processing, then the process of melting of the material was carried out and finally the advanced technology made all these feasible materials to convey towards detecting more beneficial materials.

Composite materials is an advanced material are used in various sectors due to its some outstanding properties such as density, stiffness, thermal and mechanical [1].The composite material is planned in such a way that the specific component hold their properties are so merged that the composite take advantage of their higher properties without compromising on the weakness of either [2]. There are three major types of composite materials available as per the matrix material used. The matrix material may be polymeric, metallic or ceramic. Due to the presence of the polymer material, the composite is called polymer matrix composite or PMCs. Due to the addition of reinforcements into a polymer is termed as "Polymer Matrix Composite" or shortly PMCs.

Large number of polymeric materials (thermosetting & thermoplastics) are used in the composites as a matrix. Polymeric material have been finding large advantage in the industry as an important engineering materials. For centuries, the use of polymers in everyday life has become an important part of human life. The large number of small molecules known as monomers jointly form polymers or that repeating units that can be linked together to form long chains and are known as macromolecules. This specific long chain like structures are responsible for their intriguing properties due to their wide range of stiffness, strength and heat resistance capacities. Human beings have taken advantage of the usefulness of polymers for years in different fields of consumer durables such as electrical and electronics equipment, aerospace application, packaging materials, medical equipment, automobile sectors, constructions and other engineering applications. However, the pure form of polymer would not be able to satisfy the demands for various applications, where a combination of good mechanical and wear properties are required. Hence to get supplementary strength reinforcement are added to the polymer. Composite materials are used in various sectors due to its continuous improvement of properties. The significance of composites as engineering materials is mirrored because 200 types of composite materials are used out of 1600 engineering materials that are existing in the market now a days.

1.2 Composites:

A typical composite material is a system of materials, composing of two or more materials (mixed and bonded) on a macroscopic scale [3]. Composites consist of one or more discontinuous phases embedded in a continuous phase. The discontinuous phase is usually harder and stronger than the continuous phase and is called the ‘reinforcement‘ or ‘reinforcing material’, whereas the continuous phase is termed as the ‘ matrix’. Generally, a composite material is composed of reinforcement (fibers, particles, flakes, and/or fillers) embedded in a matrix (metals, polymers or ceramics). The matrix holds the reinforcement to form the desired shape, while the reinforcement improves the overall mechanical properties of the matrix. When designed properly, the new combined material exhibits better strength, than would each individual material.

As defined by Jartiz [4], Composites are multifunctional material systems that provide characteristics not accessible from any discrete material. They are cohesive structures made by physically combining two or more compatible materials, different in composition and characteristics and sometimes in form. Considering the past, over the last fifty years, the applications of future materials like ceramics, plastics are creating a high demand in the technical sector, in comparison to the monolithic materials. Among these, some developed materials like composites are emerging steadily, because of their superior properties, both in engineering as well as non - engineering applications.

1.3 Classification of Composites.

Composites can be categorized in many ways [5]. But a distinct categorization is existing in the Fig. 1.1

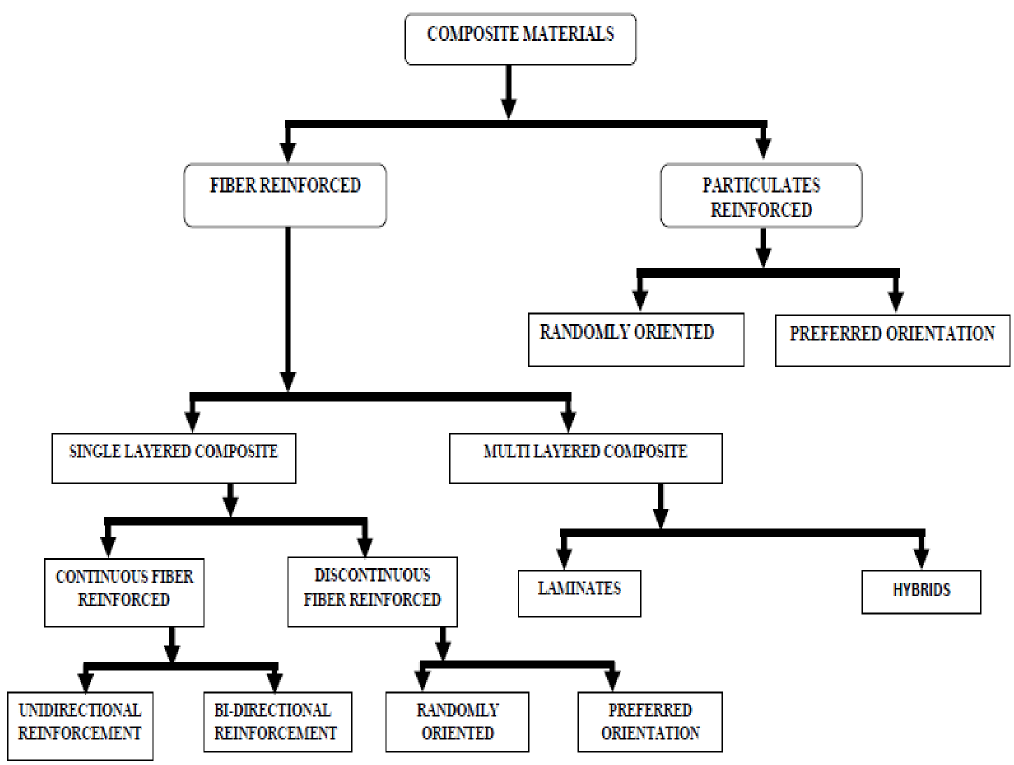


Fig1.1

1.4 Components of a composite:

As discussed earlier, a composite material consist at least two elements which work together, to produce material properties that are different to the properties of the elements on their own. In practice, composites consist of a bulk material, termed as ‘Matrix’, and reinforcement/fillers of some kind, which are added primarily to increase the strength, stiffness and the required properties of the matrix, and, finally improve the desired properties of the prepared composites.

1.5 Bio composites:

Bio composite is a material formed by a matrix and a reinforcement of a plant derived fiber. It is needed to develop novel bio based products and other innovative technologies that can reduce widespread dependence on fossil fuels. Eco-friendly bio composites from plant derived fiber and crop-derived plastics, make a great importance to the environment and is also a solution to the uncertainty of petroleum supply. Bio polymers are now moving mainstream use, and the polymers that are biodegradable or based on renewable feedstock may soon be competing with commodity plastics, as result of the sales growth of more than 20-30% per year and improvement in the economics of sales. The best examples of biopolymers based on renewable resources are: cellulosic plastics, polylactides (PLA), starch plastics and soy based plastics. Microbial synthesized biopolymers, i.e., polyhydroxy alkanoates (PHAs) polymers are also having attractive environment friendly properties. The use of materials from renewable resources is being popular and the world‟s leading industries are looking forward to use more and more composite materials derived from natural fibers and bio-polymers in place of petrochemical- based feedstock.

1.6 Classification of Natural/Bio-fibers:

Natural/bio-fibers can be broadly separated into two groups: non-wood fibers and wood fibers. At present level of technology non wood fibers like hemp, kenaf, flax and sisal find commercial success in the design of bio-composites from polypropylene for automotive applications. Increase use of biopolymers would result in more eco-friendly bio- composites for twenty first century green automotive parts applications. All the natural reinforcing fibers are lingo-cellulosic, having cellulose and lignin as principle components.

1.7 Application of natural fiber composites:

The natural fiber composites can be very cost effective material for the following applications. In the building and construction industry it is used for the separating the walls, for screen boards, floors, roof tiles etc. The composite materials are also used for manufacture of storage devices. It is also used for manufacture of house hold furniture. It has also wide range application in transport sectors, manufacture of electrical instruments, toys etc. It has also good mechanical and physical properties and low density which is suitable for the automotive industries.

However as per the suggestion of the investigator there is no information available on the mechanical behavior of fruit waste. There is little work done by Abdul Khalil *et.al* [6] to characterize the epoxy composite filled with the natural fibers like bamboo stems, coconut shells and oil palm bunches. Their results showed that there was improvement in thermal stability of the carbon black filled composite compared to the neat epoxy. Christian J.Espionze Santos [7] performed details characteristics studies on coconut fibers. He observed that increase in weight percent of fiber reinforcement increase the flexural strength of the composite. Keeping all these in view in the present work an attempt has been made to study the mechanical and flexural behavior of orange peel reinforced epoxy composite.

The composition of some commonly used natural fibers are listed in Table 1.1

Fiber	Lignin (wt. %)	Hemi-Cellulose (wt. %)	Cellulose (wt. %)	Moisture (wt. %)	Pectin (wt. %)	Waxes (wt. %)
Cotton	-	5.7	85-90	7.85-8.5	0-1	0.6
Bamboo	32	0.5	60.8	-	-	-
Flax	2.2	18.6-20.6	71	8-12	2.3	1.7
Kenaf	8-13	21.5	45-47	-	3-5	-
Jute	12-13	13.6-20.4	61-71.5	12.5-14	0.2	.5
Hemp	3.7-5.7	17.9-20.4	70-74	6.2-12	0.9	.8
Ramie	0.6-0.7	13.1-16.7	68.6-76	7.5-17	1.9	.3
Banana	5	10	63-64	10-12	-	-

Like the above natural fibers, orange peel is also one of the important natural fiber available in India. Orange peel is produced as a Fruit waste in huge quantity. It is a citrus fruit mainly found in South Asia. It is acidic nature having PH range 2.9 to 4.0. Orange peel, is the outer covering which covers the orange mainly contains cellulose, essential oils, proteins and carbohydrates. In this work efforts have been given to integrate orange peel in polymers so that they can boost the physical, mechanical and tribological properties of the latter.

1.8 Thesis Outline:

The remaining of thesis is arranged as follows:

Chapter 2: Literature: This chapter contains the previous work which is required as the reference in the present research work.

Chapter 3: Materials and procedures: Description of the materials and details of experimental methods used for this research work is represented in this chapter.

Chapter 4: Result and discussions: The results from the mechanical properties and abrasive wear behavior of the composites are represented in this chapter. Results are discussed in this chapter

Chapter 5: Conclusions: Conclusions from the above work and recommendations for future work are presented in this chapter.

Chapter 6: References: Details of references which are required for the above research work are listed in this chapter.

Chapter-2

LITERATURE SURVEY

2.1 Literature survey:

Literature study is maintained to get the evidence for the present research work and to give the attention to the importance of the present research work. The purpose is to study the physical and mechanical properties thoroughly by taking various aspects of natural fiber composites.

2.2 Natural fibers: Initiative in product Development.

In the fiber reinforced polymer composite natural fibers or synthetic fibers used as reinforcement. Cellulose is the main component of Natural fibers containing of helically wound cellulose micro fibrils which is bound together by the help of amorphous lignin matrix. Due to presence of lignin water is inside the fiber and it prevents from any biological attack and averts the stem from gravity forces and from wind act as a stiffener. The role of compatibilizer between cellulose and lignin is done by hemicellulose which is present in natural fiber in between cellulose and lignin [8].The use of natural fiber has been increasing since last decade in place of synthetic fibers such as glass fiber due to its certain special properties such as low density, easy availability, biodegradability, low cost, good mechanical properties and nontoxic in nature [9]. It has been used for different industrial sectors such as aerospace, packaging, automobiles, transportation [10, 11] and even in building sectors [12]. Same kind of Natural fibers may have different chemical compositions due to growing conditions and different test methods. The chemical composition of natural fibers play a vital role on the physical and mechanical properties of natural fiber reinforced polymer composites [13]. By taking same modulus it has been seen from the above table that the glass fiber has high tensile strength than that of natural fiber. However natural fiber is better in comparison to synthetic fiber by considering specific modulus. Natural fibers used as reinforcement in FRP composites for weight sensitive application due to their higher specific properties is the major advantages.

Natural fibers are derived either from plant or from animal sources. The plants are the common useful natural fibers except wool and silk. The Plant fibers are mainly consist of cellulose whereas proteins are the main component of animal fibers. By considering origin as the source, natural fibers are classified and the plant based fibers can be further classified based on they are recovered from. A summary of natural fiber is presented in the below given figure.

The characteristics of some natural fibers which was used as the reinforcement in the FRP composites as listed in the given table along with E-glass fiber. From above table it is clearly mentioned that the glass fiber has higher value of Tensile as well as Flexural strength but natural fibers are used as the replacement glass fiber due to its higher specific properties.

Table 2.1 Characteristics of natural fibers [14]

Fiber	Tensile strength (MPa)	Young's modulus (GPa)	Elongation at break (%)	Density (g/cm^3)
Abaca	401	11	4-12	1.5
Alfa	349	21	5.9	0.91
Bagasse	291	18	-	1.26
Bamboo	141-231	11-18	-	.6-.12
Banana	495	12	6.1	1.32
Coir	174	5-8	31	1.3

Cotton	281-598	5.5-1.6	8-9	1.5-1.7
Curaua	501-1151	11.9	3.8-4.4	1.5
Palm	98-197	2.6-5.5	2-4.6	1-1.3
Flax	346-1036	28.6	2.8-3.3	1.6
Hemp	691	71	1.7	1.49
Henequen	501±71	13.4±3.3	4.9±1.3	1.3
Isora	501-602	-	5-8	1.3-1.4
Jute	394-774	27.6	1.6-1.7	1.3
Kenaf	931	55	1.7	-
Nettle	659	40	1.8	-
Oil palm	249	3.4	27	0..8-1.56
Piassava	135-144	1.08-5.2	22-8.0	1.5
Pineapple	401-628	1.44	14.7	0.8-1.9
Ramie	559	25.7	2.6	1.6
Sisal	512-636	9.5-24	2.0-2.7	1.6
E-glass	3402	75	-	2.6

A lot of study has been done by using various factors on the mechanical and physical behavior of natural FRP composites. The impact behavior of Jute fiber reinforced polyester composites has been studied at low velocity impression by Santulli [15].The tensile and flexural properties of pineapple fiber reinforced poly composites has been studied by Luo and Netravalli [16]. Schneider and Karmakar [17] investigated that jute fiber provides better mechanical characteristics in comparison to kenaf fiber by taking jute and kenaf as the reinforcement and polypropylene as the matrix material. The mechanical properties of jute/glass reinforced epoxy based hybrid composites has been studied by Srivastav [18] by taking various load rates. The mechanical properties of jute fiber reinforced polyester composites has been studied by Gowda [19]. Form the above study it is clearly visible that jute fiber based composite have higher strength as compare to composites having wood as the reinforcement. Though lot of advantages is associated with natural fiber composites but still they have some major disadvantages which is the reason behind the limited use of natural fiber composites. The efficient stress transfer in fibers is generally very low due to stick to common non polar matrix material. The inherent hydrophilic nature of fibers makes them inclined to water to uptake in moist conditions. Due to water uptake the natural fiber composites tend to swell and as a significance the mechanical properties such as strength and stiffness are negatively influenced. The fiber matrix bond may be enriched and the fiber enlargement was reduced [20] by chemical modifications, enzymatic modifications and chemical modifications.

A lot of research works have been studied in the last few years to replace conventional fiber with natural fiber composites [21, 22, 23-27].By adding cotton as the reinforcement Hasmi [20] got better wear properties in comparison to matrix material. Tong [28] studied the abrasive wear behavior using bamboo as reinforcement and got that the abrasive wear depends upon the fiber orientation with regard to abrading surface and particle size. Similarly the Rice husk the natural fiber has potential for replacement of synthetic fiber as a reinforcement in FRP composite [29]. By compression or injection molding process Vinay Kumar [30] studied polymer composites taking rice husk as reinforcement and polypropylene as matrix. From the literature survey we found that the waste fibers may be used for preparation of different natural FRP composites since they have attractive physical and mechanical properties.

2.3 Summry of the previous work:

A lot of work has been done by using natural fiber as reinforcement resulting of the improvement of physical and mechanical properties comparison to matrix material. But the absorption of moisture is the major disadvantage in case of natural fiber FRP composite. So to increase the quality of natural fiber reinforced composite lot of research work would be required.

Various natural fibers has been taken for FRP composite and lot of research has been done so far but still no research work has been done so far by taking orange peel as the natural fiber.

2.4 Objective of the research work:

The objectives of the present work are listed below

- Prepare the desired size orange peel particulates.
- Fabricate the particulate with different weight percentage in the epoxy matrix.
- Study the density of different samples.
- Check the micro hardness of different samples.
- Study the mechanical properties of different samples.
- Study the abrasive behaviour of different samples.
- Conduct the SEM for different samples to study the nature of failure at the microscopic level.

Chapter-3

MATERIALS AND METHOD

3.1 Introduction:

Wear is a feature of the engineering system that is administered by load, speed, temperature, hardness, that existence of external material and environmental condition [31]. Extensively varied wearing conditions cause wear of materials. It is due to the surface damage or removal of material from one or both of two solid surfaces in a sliding, rolling or impact motion relative to one another. The wear occurs in most of the cases at the asperities through surface interactions. During the relative motion,the material on contacting surface may be removed from a surface, may result in the transfer to the mating surface, or may break loose as a wear particle. The wear research programme must be done thoroughly because wear of the materials depends upon many variables. Therefore, it is required to normalise some of the data to make them more beneficial. Lim [32] projected the roadmap that is more helpful to know the wear mechanism in different sliding conditions, and the expected rates of wear.In these works the wear resistance of polymeric composites have been improved when natural fiber (orange peel) used as reinforcement.

3.2 Types of wear:

Wear may be categorised as

- Abrasive wear
- Adhesive wear
- Erosive wear

3.3. Abrasive wear:

When a hard surface slides against and cuts groove from a softer surface wear arises, is defined as Abrasive wear. Most failures in practice is due to abrasive wear. The cut or groove one of the rubbing surfaces due to hard particles or asperities produce abrasive wear. The hard particles may be instigated from one of the two rubbing surfaces. The abrasive wear is classified as (i) Two body abrasion and (ii) Three body abrasion.

Two body abrasion: A rough, hard surface slides against a comparatively soft mating surface is known as two body abrasion.

Examples of two-body abrasion are grinding, cutting and machining.

Three body-abrasion: In three-body abrasion rough, hard particles trapped between two sliding surfaces cause one or both of them to undergo abrasive wear.

Examples are free abrasive lapping and polishing.

According to the recent tribological survey, the large amount of material loss in industrial practice is due to abrasive wear.

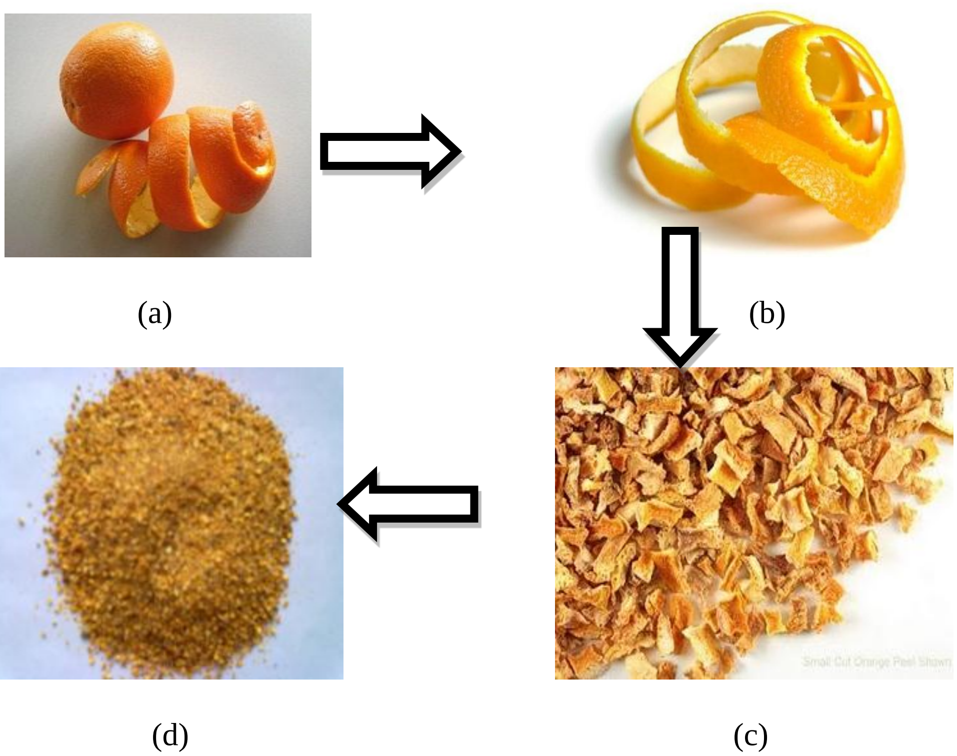
3.4 Materials and Technique:

The ingredients required in this research work are given below

1. Natural fiber (Orange peel)
2. Epoxy Resin
3. Hardener

3.4.1 Orange peel:

Orange has a long, problematical history, in part because it is not an uninhabited fruit. Rather, it is a carefully sophisticated hybrid of mandarin and pomelo. The countries where that the oranges are cultivated first is northeastern India, southern China, and Indochina. Oranges are a key crop for India, place only after bananas and mangos in volume. India ranked third in the world for cultivation of oranges, behind Brazil and the United States by UN's. Food and Agriculture Organization (FAO) published in 2010. Combiely, these three countries produced almost half of the world's production of 68 million tons. India ships oranges to countries including Sri Lanka, France, the UK, Belgium, and Bangladesh. It is the most typically grown tree fruit in the world. Like all citrus fruits, the orange which is acidic in nature has PH range 2.9-4.0.Orange peel, the outer cover part of an orange, mainly consists of cellulose, essential oils, proteins and some simple carbohydrates. The orange peels were collected locally. Then they were sun dried for 4-5 days to remove the moisture from the orange peels. The fibres were then grinded into fine powder as shown in figure 3(a), (b),(c),(d). The collected powders were separated and After sieving a particle size of 100 micron meter has been taken in accordance with BS1377:1990[12]3.1.



(a) (b) (d) (c)

Fig 3.1(a), (b), (c),(d): Orange Peel fiber and particulate

3.4.2 Epoxy resin:

The epoxy resin Araldite LY556 is used in the present research work which is in the epoxide family. BisPhinol-A-Diglycidyl-Ether is the common name of the above epoxy resin. It is provided by CIBA GUGYE India Limited. Epoxy resins(ER) which is used as matrices for fiber reinforced composites is in the class of thermosetting polymers. They are amorphous and highly cross linked polymers. Due to this structure it has high tensile strength and modulus, good thermal and chemical resistance.

3.4.3 Hardener:

HY951 is the hardner used in this research work with epoxy. It has a viscosity of 20-30 MPa at 30ºC.

3.5 Composite preparation:

A Per-pex sheet mould (dimension 130X100X6mm) figure-3.2 was used for the preparation of composite sheet. A spray was used at the inner surface of the mould for smooth release of composite. For the preparation of different weight fraction of the sample a calculated amount of epoxy and hardener in the ratio of 10:1 has been taken and mixed with required amount of orange peels. The mixture was stirring properly to reduce air set up set-up. By taking sufficient care the mixture was poured in to wax coated glass sheet, so that creation of air bubble should be avoided. Load was then applied from the upper and the mould was allowed to cure for 2 to3 days. During manufacturing sufficient care should be taken to get a constant thickness because by application of load some of the mixture might be come out. This procedure was adopted for preparation of 10, 20 and 30% weight fractions of orange peels. After the completion of time limit the samples were removed from the mould and prepare into required size for the further research work.

3.6 Experimental Procedure:

The following tests were conducted on the above samples:

a. Density measurement

b. Hardness test

c. Tensile test

d. Flexural test

e. Dry sliding wear test

3.6.1 Density Measurement:

The density of composite materials in terms of volume fraction is found out from the following equations

$$\rho_{ct} = \frac{w_0}{(w_0) + (w_a - w_b)} \tag{3.1}$$

where "ρ_{ct}" represents specific gravity of the composite,

"w_o" represents the weight of the sample; "w_a" represents the weight of the bottle + kerosene,

"w_b" represents the weight of the bottle + kerosene + sample,

Density of composite = ρ_{ct} × density of kerosene. (3.2)

The theoretical density of composite materials in terms of weight fraction is found out from the following equations as given by Agarwal and Broutman [34].

$$\rho_{ct} = \frac{1}{\left(\frac{w_f}{\rho_f}\right) + \left(\frac{w_m}{\rho_m}\right)} \tag{3.3}$$

where "w" and "ρ" represents the weight and density respectively. The suffix f, m and ct stand for the fiber, matrix and the composite materials.

The void content of composite sample has been determined as per ASTM D-2734-70 standard procedure. The volume fraction of voids (v_v) in the composites was calculated by using equation (3.4).

$$v_v = \frac{\rho_t - \rho_a}{\rho_t} \quad (3.4)$$

where "ρ_t" and "ρ_a" are the theoretical and actual density of composite respectively.

3.6.2 Hardness Test:

Hardness is the resistance of a material to deformation, indentation or scratching. It can differentiate the grades of various polymers with hardness number and also reveals the dimensional stability of a material. The indentation value has high importance for technical applications which reflects the resistance to deformation, which is a complex property and related to modulus, strength, elasticity, plasticity and dimensional stability of a material. Hardness is generally classified into three categories with respect to the depth of indentation(d) as follows.(a) Nano hardness(d<1μm) ,(b) Micro hardness(d=1-50 μm) and(c) Macro hardness(d>50 μm).The test methods commonly used for expressing the relationship between hardness and size of impression are Brinell,Vicker's and Rockwell hardness tests. In this study, Vickers's hardness test setup is used to find out the micro hardness value of polymer composites. Leitz Micro –hardness tester was used for Hardness measurement. Vickers hardness number is calculated by using the following equations.

$$L = \frac{(X+Y)}{2} \quad (3.5.a)$$

$$H_v = 0.1889\ \frac{F}{L^2} \quad (3.5.b)$$

Where" F" is the applied load, "L" is the diagonal of square impression (mm), "X" is the horizontal length (mm), and "Y"is the vertical length (mm).

3.6.3 Tensile Test:

The tension test is generally performed on flat specimens. The most commonly used specimen geometries are the dog-bone specimen, figure-3.3, and straight-sided specimen with end tabs. The standard test method as per ASTM D3039-76 has been used. The length of the test specimen used is 150 mm. The tensile test has been performed in universal testing machine (UTM) INSTRON H10KS. The tests were performed with a cross head speed of 0.5mm/min. For each test composite of four samples were tested and average value was taken for analysis.

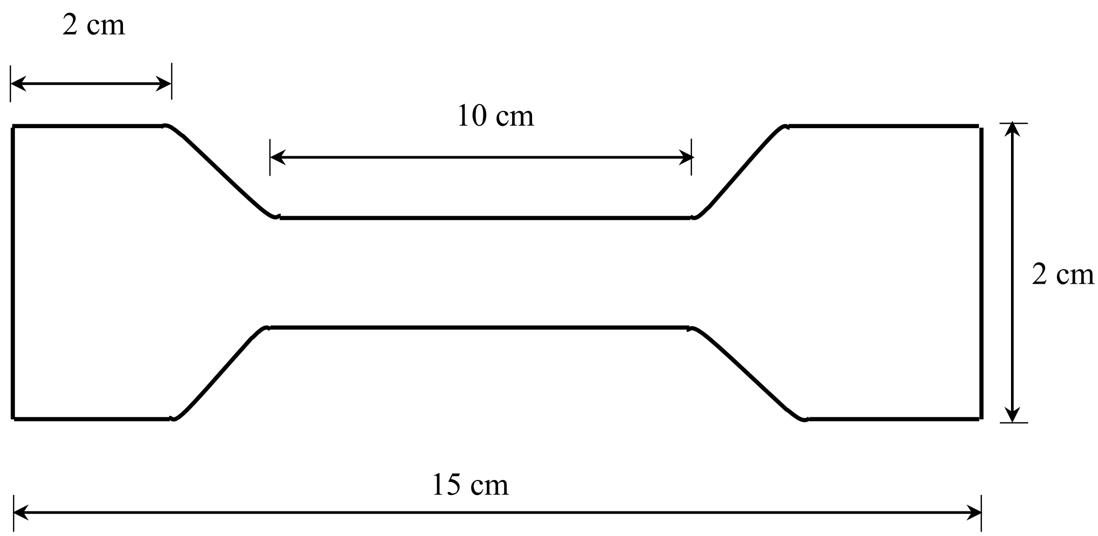


Figure 3.2 Dog bone shape of the tensile testing sample

Figure 3.3 (a) UTM Machine Sample holder **(b)** UTM Machine Sample Loaded

3.6.4 Flexural Strength:

The three point bend test was carried out in UTM machine in accordance with ASTM D2344-84 to measure the flexural strength of the composites. The loading arrangement for the specimen and the photograph of the machine used are shown in Figure-3.5(a) and (b) respectively. The entire specimens were of rectangular cross section of (150x20x5) mm. A span of 100 mm was used for the test specimen. The specimens were tested at a crosshead speed of 0.5mm/min. The flexural strength in a three point bending test is found out by using equation (3.6).

$$\sigma = \frac{3FL}{2bt^2} \tag{3.6}$$

where "σ" is the flexural strength, F is the load, L is the gauge length, b is the width and t is the thickness of the test specimen.

The short beam shear tests (SBS) are performed on the composite samples at room temperature to evaluate the value of inter-laminar shear strength (ILSS). It is three point bending test which generally promotes failure by inter-laminar shear. The test is conducted as per ASTM standard using the same UTM, span length 100mm and cross head speed 0.10mm/min.

The inter-laminar shear strength (ILSS) is found out by using the equation (3.7).

$$ILSS = \frac{3F}{4bt} \tag{3.7}$$

where F is the load, b the width of the specimen and t is the thickness of the specimen.

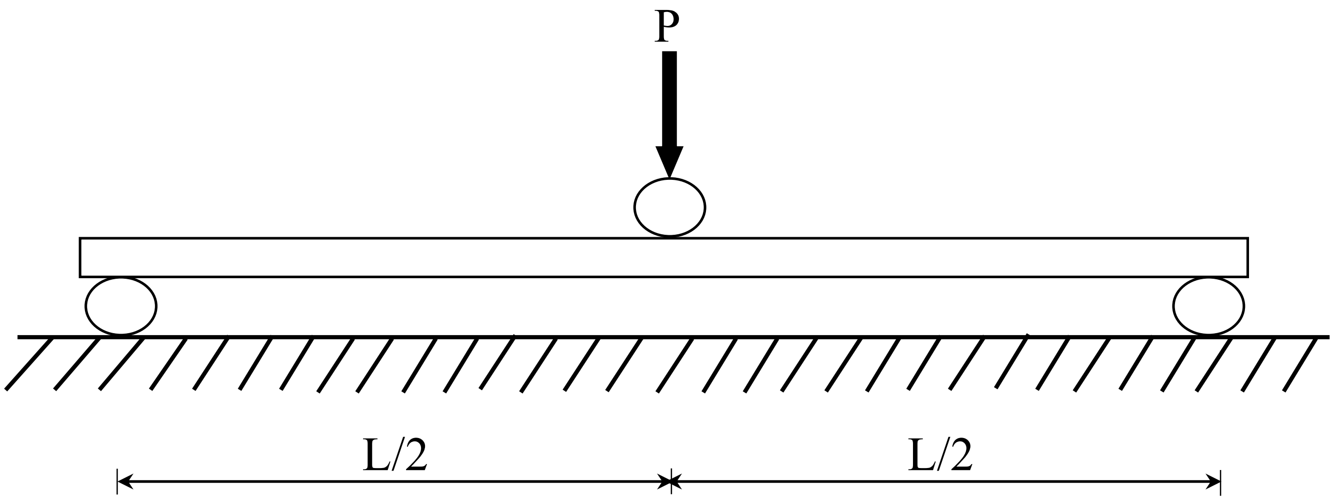


Figure (3.4(a)) the loading arrangement for flexural testing

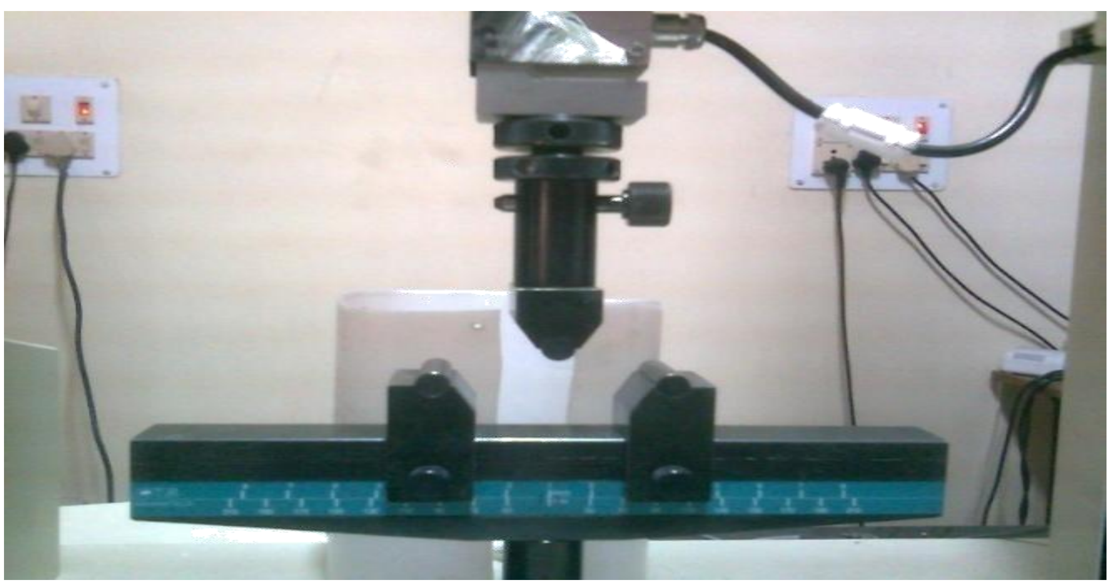


Figure 3.4 (b) Flexural specimen loading position

3.7 Preparation of Specimens for Dry Sliding wear test:

The fibres were prepared as per the procedure explained in Art-3.6.A calculated amount of epoxy resin and hardener(ratio of 10:1 by weight) was thoroughly mixed in a glass jar and placed in a vacuum chamber(10,20,30wt%) were added and mixed accurately. A steel mould which has been designed and fabricated in the workshop is used for preparation of cylindrical (pin) type specimen of length 35mm and diameter of 10 mm which is shown in Figure-3.10.The mixture has been poured into cylindrical cavity present in the mould and then two halves of the mould are fixed properly. During fixing some of the resin mix may enfolded out. Sufficient care has been taken for pressing out of resin mix during preparation of composites. After closing of the mould the specimens were allowed to solidify in the mould at the room temperature for 24 hrs. For the purpose of comparison the matrix material was also cast under similar condition. After curing the samples were taken out from the mould, finished ground to required shape, sizes for wear testing.

3.8 Dry sliding wear test:

Dry sliding abrasive wear test was conducted on a pin-on-disc machine according to ASTM G-99 standard which was provided by Magnum Engineers, Bangalore. An abrasive paper of 400 grades (grit-23 µm) has been glued on the rotating disc (EN31) of diameter120 mm. The sample holder contains the specimen was located at a distinct track diameter. The diameter of track was changed after each test or new and fresh surface is to be supplied for each specimens. For each test new abrasive paper was used. Track radius of 50 mm was taken for testing and kept consistent for whole experiment. During testing specimen remain fixed and the disc rotates. By the help of dead weight loading system load was exerted to press the pin against the disc. A control panel was provided in machine to vary the speed of the disc and time period. The total duration for testing of single specimen was 25mins. By calculating the weight of specimen before and after each test the mass loss can be determined. Before and after testing specimen should be cleaned with acetone.

Table-3.3: Test parameters for Dry Sliding wear test

Test parameters	**Units**	Values
Weight fraction of fiber	%	0,10,20,30
Load(L)	N	5.0,7.5,10.0,15.0,20.0
Sliding Velocity(v)	m/s	1.0471,1.5709,2.094
Track radius ®	m	.05
Temperature	0^0C	25

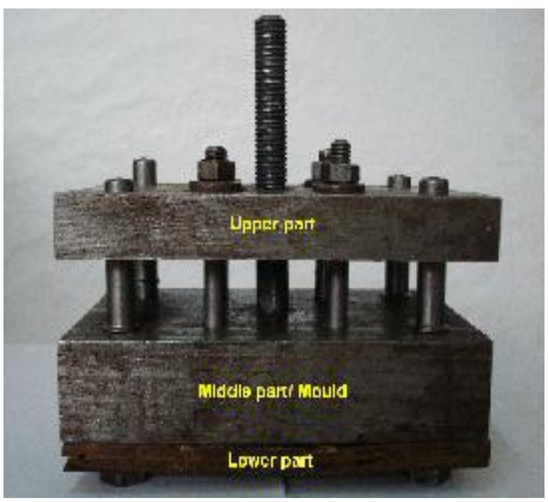


Figure 3.5(a) Steel Mould (b) Composite Samples

3.9 CALCULATION FOR WEAR:

Wear rate was estimated by measuring the mass loss of the specimen after each test. The **mass loss** was calculated by taking the weight difference of the sample before and after each test. The mass loss:

$$(\Delta m) = (m_a) - (m_b)\ gm \tag{3.8}$$

where, Δm = weight loss in gm, m_a = weight of specimen prior to testing in gm, m_b = weight of specimen after testing in gm.

Dry sliding abrasive wear rate (W) can be determined by using the following formula:

$$W = \frac{\Delta m}{\rho \times SD}\ mm^3/m \tag{3.9}$$

where, ρ = density of the composite in g/cm^3 , SD = sliding distance in meter

Volumetric wear rate (W_v) of the composite which depend upon density (ρ) and the abrading time (t), can be determined using following formula

$$W_v = \frac{\Delta m}{\rho \times t}\ m^3/s \tag{3.10}$$

The abrasive wear performance of composite can be classify using the **specific wear rate (**W_s) which is defined as the volume loss of the composite per unit sliding distance and per unit applied load. It can be determined by using following expression

$$W_s = \frac{\Delta m}{\rho \times SD \times F}\ m^3/Nm \tag{3.11}$$

where, Δm is the mass loss in grams, SD is sliding distance in meter and F is the applied normal load in N.

Coefficient of friction (μ) can be determined by using following equation:

$\mu = \frac{F_f}{F}$ Where, F_f is the frictional force in N obtained from control panel directly and F is the applied normal force in N.

The values of weight loss, wear rate, volumetric wear rate and specific wear rate for each batch is listed in the table from4.5 to 4.64.

Chapter-4

RESULTS AND DISCUSSION

4.1 Density measurement:

From the table-4.1it is clearly observed that the void fraction in the composite increases as the wt. percentage of reinforcement increases, but the percentage of void fraction is very less so the preparation of sample is optimum level. It is also observed that the density gradually increases by increasing the percentage of reinforcement. But at 30 wt. percentage the density decreases due to increase of void percentage.

Table-4.1: (Density of various samples)

Fiber content (%)	Measured density(gm/cm^3)	Theoretical density(gm/cm^3)	Volume fraction of Voids (%)
Epoxy	1.1	1.189	.074
10	1.116	1.223	.088
20	1.145	1.261	.091
30	1.138	1.299	.124

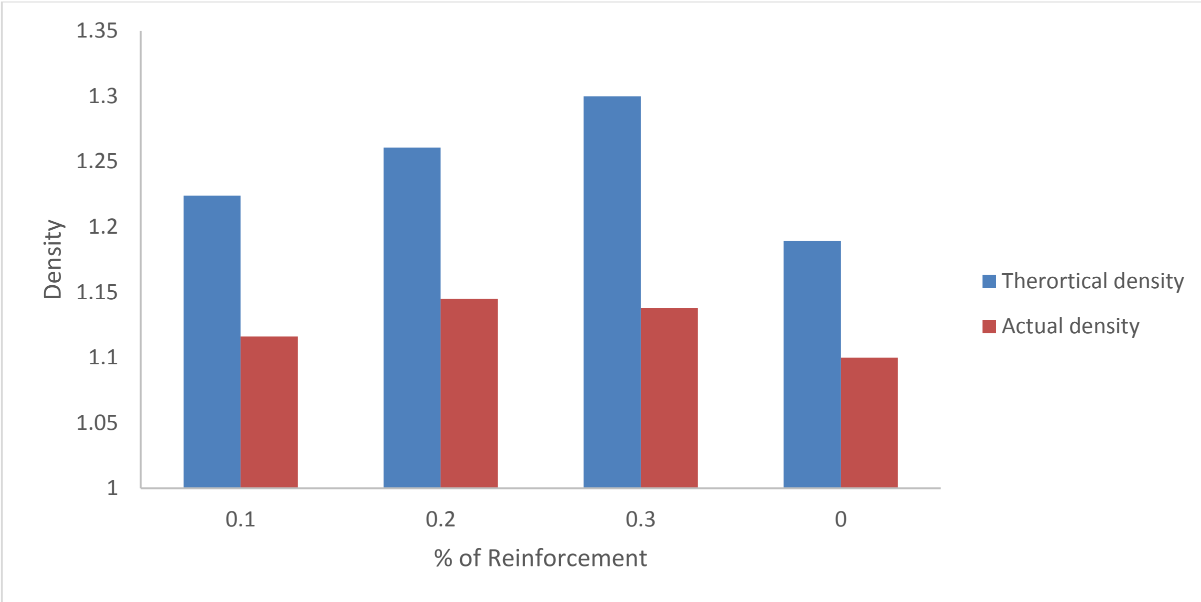


Figure-4.1(Variation of theoretical and actual density with different fiber content)

4.2 Hardness test:

The hardness value of composite is measured by Leitz-Micro- hardness tester. The results are tabulated are in table 4.2. By increasing the reinforcement the hardness of composite increases and the maximum value obtained for 20% composite.

Table-4.2: (Hardness of different samples)

Weight fraction of fiber (%)	Vickers hardness value
0(%)	18.894
10(%)	20.68
20(%)	21.75
30(%)	19.95

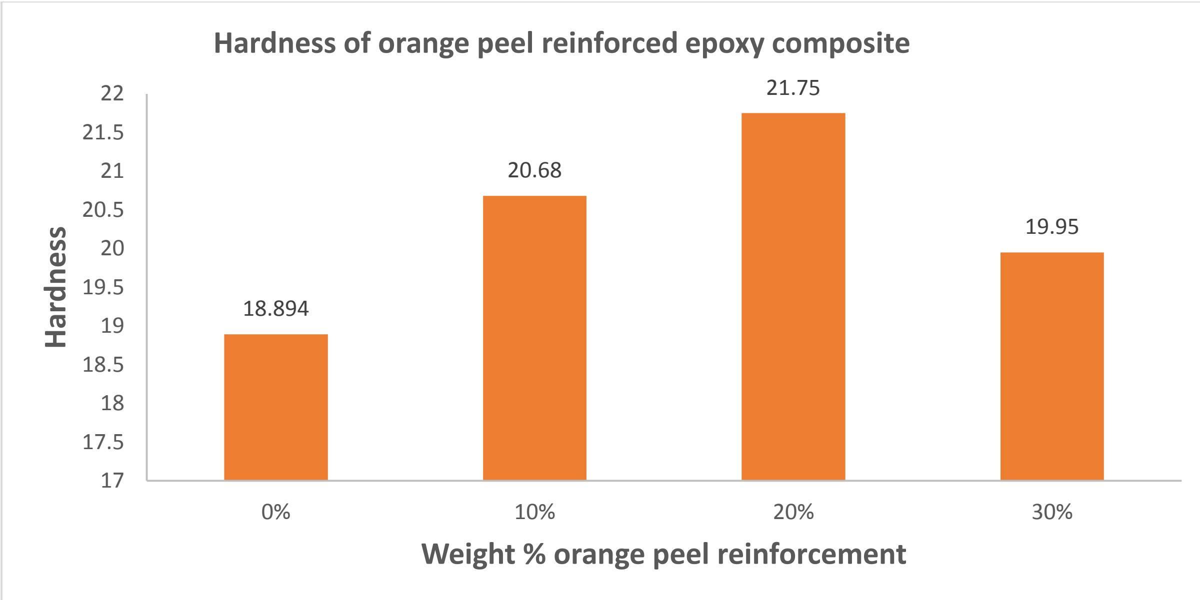


Figure-4.2 (Variation of Hardness value with different % of fiber content.)

4.3 Tensile strength:

The tensile tests of different samples measured by UTM are tabulated in table 4.3. From the given table it is observed that the tensile strength goes on increasing and gives maximum strength for the composites with 20% fiber weight fraction in comparison due to void content.

Table-4.3: (Tensile strength and tensile modulus of different samples)

Fiber content by weight (%)	Tensile strength (Mpa)	Tensile modulus (Mpa)
Neat epoxy	18.131	649.23
10	23.70	1315.63
20	26.85	1270.69
30	22.34	937.96

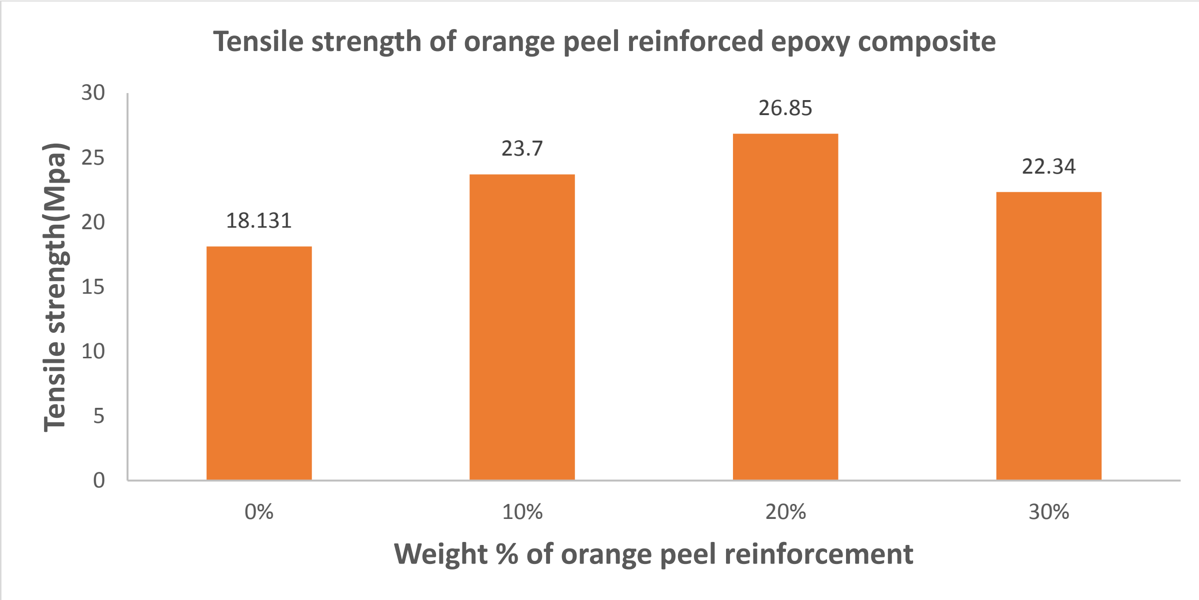


Figure 4.3 (Variation of tensile strength with increasing % of orange peel reinforcement in the composite.)

4.4 Flexural strength:

The flexural strength of different composites measured by UTM 201 machine in accord with ASTM D2344-84.Table 4.4 represents the flexural strength, the flexural modulus and ILSS values for different samples containing different weight percentage of particulates.

Table 4.4: (Flexural strength, Flexural modulus and ILSS)

Weight fraction of particulates (%)	Flexural strength(Mpa)	Flexural modulus(Gpa)	ILSS(Mpa)
Neat epoxy	46.519	6.046	1.237
10	57.98	10.631	1.753
20	63.35	11.970	1.908
30	58.89	9.334	1.865

From the above table it is found that the flexural strength, flexural modulus and ILSS is maximum for composites having 20% fiber content.

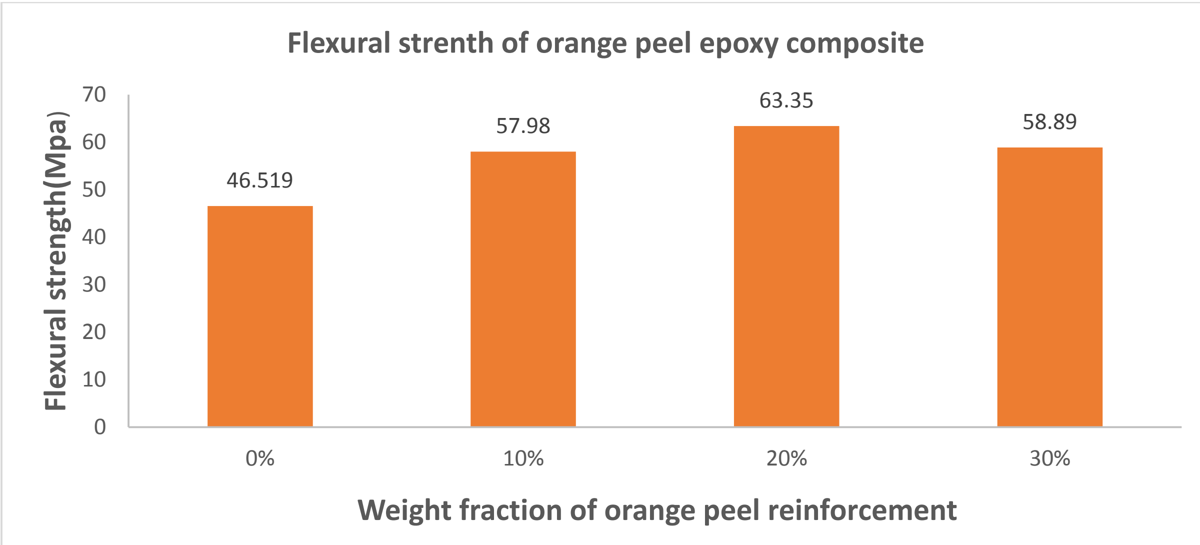


Figure 4.4 (Variation of flexural strength with increasing weight fraction of orange peel reinforcement in the composite.)

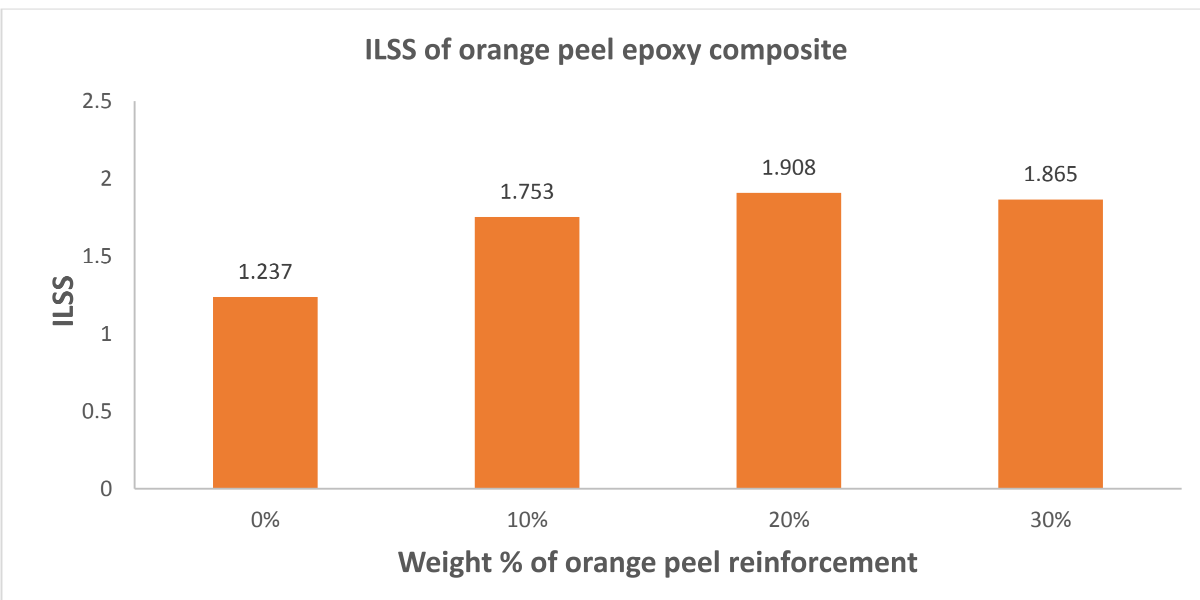


Figure-4.5 (Variation of ILSS of orange peel epoxy composite with weight % of orange peel reinforcement.)

Table 4.5:

Weight Fraction- 0% **Load- 5 N** **Velocity – 1.0471 m/s** **RPM-200**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	F_f (N)	μ	Sd $X10^3$ (m)	Wr$X10^{-11}$ (m^3/m)	Wv$X10^{-11}$ (m^3/Nm)	Ws$X10^{-10}$ (m^3/s)
2.64	2.41	0.23	300	4.857	0.971	0.471	44.393	69.697	8.878
2.64	2.35	0.29	600	4.809	0.961	0.942	27.986	43.939	5.597
2.64	2.3	0.34	900	4.709	0.941	1.414	21.859	34.343	4.371
2.64	2.25	0.39	1200	4.759	0.951	1.885	1.880	29.545	3.761
2.64	2.22	0.42	1500	4.801	0.960	2.356	16.206	25.454	3.241

Table 4.6

Weight Fraction- 0% **Load- 5 N** **Velocity – 1.571 m/s** **RPM-300**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	Sd $X10^3$ (m)	F_f (N)	μ	Wr$X10^{-11}$ (m^3/m)	Ws$X10^{-11}$ (m^3/Nm)	Wv$X10^{-11}$ (m^3/s)
3.401	3.29	0.111	300	0.314	4.806	0.961	32.136	21.714	6.427
3.401	3.24	0.161	600	0.628	4.756	0.951	23.306	18.009	4.661
3.401	3.2	0.201	900	0.942	4.659	0.931	19.397	15.904	3.879
3.401	3.15	0.251	1200	1.257	4.708	0.941	18.152	14.736	3.630
3.401	3.12	0.281	1500	1.571	4.659	0.931	16.267	13.804	3.252

Table 4.7

Weight Fraction- 0% **Load- 5 N** **Velocity – 2.094 m/s** **RPM-400**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	Sd X10^3 (m)	F_f (N)	μ	WrX10^{-11} (m^3/m)	WvX10^{-11} (m^3/Nm)	WsX10^{-10} (m^3/s)
3.21	2.85	0.36	300	0.628	4.857	0.971	52.113	1.090	10.422
3.21	2.75	0.46	600	1.257	4.808	0.961	33.268	6.969	6.653
3.21	2.75	0.46	900	1.885	4.759	0.951	22.184	46.464	4.436
3.21	2.75	0.46	1200	2.513	4.759	0.951	16.640	34.848	3.328
3.21	2.75	0.46	1500	3.142	4.708	0.941	13.309	27.878	2.661

Table 4.8

Weight Fraction- 0% **Load- 7.5 N** **Velocity – 1.047 m/s** **RPM-200**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	Sd X10^3 (m)	F_f (N)	μ	WrX10^{-11} (m^3/m)	WvX10^{-11} (m^3/Nm)	WsX10^{-10} (m^3/s)
2.88	2.75	0.13	300	0.314	7.137	0.951	37.637	39.393	5.018
2.88	2.69	0.19	600	0.628	7.064	0.941	27.504	28.787	3.667
2.88	2.65	0.23	900	0.942	6.99	0.932	22.196	23.232	2.959
2.88	2.61	0.27	1200	1.257	7.064	0.941	19.523	20.454	2.603
2.88	2.58	0.3	1500	1.571	6.99	0.932	17.360	18.181	2.314

Table 4.9

Weight Fraction- 0% **Load- 7.5 N** **Velocity – 1.571 m/s** **RPM-300**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	Sd X10^3 (m)	F_f (N)	μ	WrX10^{-11} (m^3/m)	WvX10^{-11} (m^3/Nm)	WsX10^{-11} (m^3/s)
2.37	2.08	0.29	300	0.471	7.211	0.923	55.973	87.878	7.4631
2.37	1.99	0.38	600	0.942	7.137	0.911	36.672	57.575	4.889
2.37	1.91	0.46	900	1.414	7.064	0.891	29.574	46.464	3.943
2.37	1.87	0.5	1200	1.885	7.064	0.865	24.113	37.878	3.215
2.37	1.84	0.53	1500	2.356	6.99	0.694	20.450	32.121	2.726

Table 4.10

Weight Fraction- 0% **Load- 7.5N** **Velocity – 2.094 m/s** **Rpm-400**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	Sd X10^3 (m)	F_f (N)	μ	WrX10^{-11} (m^3/m)	WsX10^{-11} (m^3/Nm)	WvX10^{-11} (m^3/s)
3	2.52	0.48	300	0.628	7.211	0.961	69.484	145.455	9.2646
3	2.4	0.6	600	1.256	7.211	0.961	43.393	90.909	5.785
3	2.32	0.68	900	1.884	7.137	0.951	32.794	68.686	4.372
3	2.27	0.73	1200	2.512	7.064	0.941	26.408	55.303	3.521
3	2.23	0.77	1500	3.141	7.064	0.942	22.278	46.666	2.970

Table 4.11

Weight Fraction- 0% **Load- 10 N** **Velocity – 1.047 m/s** **RPM-200**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	Sd X10^3 (m)	F_f (N)	μ	WrX10^{-11} (m^3/m)	WvX10^{-11} (m^3/Nm)	WsX10^{-10} (m^3/s)
3.2	3.01	0.19	300	0.314	9.517	0.952	55.008	57.575	5.501
3.2	2.93	0.27	600	0.628	9.419	0.942	39.085	40.909	3.908
3.2	2.88	0.32	900	0.942	9.419	0.942	30.882	32.323	3.088
3.2	2.84	0.36	1200	1.256	9.321	0.932	26.036	27.272	2.603
3.2	2.81	0.39	1500	1.571	9.419	0.942	22.568	23.636	2.256

Table 4.12

Weight Fraction- 0% **Load- 10 N** **Velocity – 1.571 m/s** **RPM-300**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	Sd X10^3 (m)	F_f (N)	μ	WrX10^{-11} (m^3/m)	WsX10^{-11} (m^3/Nm)	WvX10^{-10} (m^3/s)
3.64	3.31	0.33	300	0.471	9.517	0.952	6.3.694	148.484	6.369
3.64	3.23	0.41	600	0.942	9.419	0.942	3.956	98.484	3.957
3.64	3.14	0.5	900	1.413	9.419	0.942	3.214	74.747	3.215
3.64	3.03	0.61	1200	1.884	9.321	0.932	2.942	60.606	2.942
3.64	2.98	0.66	1500	2.355	9.222	0.922	2.546	50.909	2.547

Table 4.13

Weight Fraction- 0% **Load- 10 N** **Velocity – 2.094 m/s** **RPM-400**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	Sd $X10^3$ (m)	F_f (N)	μ	Wr$X10^{-11}$ (m^3/m)	Wv$X10^{-11}$ (m^3/Nm)	Ws$X10^{-10}$ (m^3/s)
2.5	1.95	0.55	300	0.628	9.517	0.958	79.618	166.667	7.962
2.5	1.79	0.71	600	1.256	9.419	0.942	51.349	107.575	5.135
2.5	1.69	0.81	900	1.884	9.419	0.942	39.064	81.818	3.906
2.5	1.62	0.88	1200	2.512	9.321	0.932	31.834	66.667	3.183
2.5	1.57	0.93	1500	3.141	9.419	0.942	26.908	56.363	2.691

Table 4.14

Weight Fraction- 0% **Load- 15 N** **Velocity – 1.047 m/s** **RPM-200**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$S_d X10^3$ (m)	F_f (N)	μ	Wr$X10^{-11}$ (m^3/m)	Wv$X10^{-11}$ (m^3/Nm)	Ws$X10^{-11}$ (m^3/s)
2.47	2.24	0.23	300	0.314	14.127	0.942	66.589	69.697	4.439
2.47	2.11	0.36	600	0.628	13.98	0.932	52.113	54.545	3.474
2.47	2.03	0.44	900	0.942	13.833	0.922	42.463	44.444	2.831
2.47	1.98	0.49	1200	1.256	13.686	0.912	35.438	37.121	2.363
2.47	1.94	0.53	1500	1.571	13.833	0.922	30.669	32.121	2.045

Table 4.15

Weight Fraction- 0% **Load- 15 N** **Velocity – 1.571 m/s** **RPM-300**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$S_d X10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-11}$ (m^3/s)
3.41	2.88	0.53	300	0.471	14.127	0.942	102.296	160.606	6.819
3.41	2.7	0.71	600	0.942	14.127	0.942	68.519	107.576	4.568
3.41	2.61	0.8	900	1.413	13.979	0.932	51.434	80.808	3.429
3.41	2.56	0.85	1200	1.884	13.833	0.922	40.993	64.394	2.733
3.41	2.52	0.89	1500	2.355	13.685	0.912	34.342	53.939	2.289

Table 4.16

Weight Fraction- 0% **Load- 15 N** **Velocity – 2.094 m/s** **RPM-400**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$S_d X10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-11}$ (m^3/s)
3.33	2.7	0.63	300	0.628	14.126	0.942	91.198	190.909	6.079
3.33	2.53	0.8	600	1.256	13.98	0.932	57.858	121.212	3.857
3.33	2.45	0.88	900	1.884	13.98	0.932	42.441	88.888	2.829
3.33	2.39	0.94	1200	2.512	13.833	0.922	34.004	71.212	2.267
3.33	2.34	0.99	1500	3.141	13.833	0.922	28.644	60.001	1.909

Table 4.17

Weight Fraction- 0% **Load- 20 N** **Velocity – 1.047 m/s** **RPM-200**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$S_d X10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-10}$ (m^3/s)
3.141	2.861	0.28	300	0.314	19.126	0.9563	81.065	84.848	4.053
3.141	2.691	0.45	600	0.628	18.979	0.949	65.142	68.182	3.257
3.141	2.561	0.58	900	0.942	18.832	0.942	55.974	58.586	2.799
3.141	2.491	0.65	1200	1.256	18.685	0.934	47.009	49.243	2.350
3.141	2.371	0.77	1500	1.571	18.832	0.942	44.558	46.667	2.228

Table 4.18

Weight Fraction- 0% **Load- 20 N** **Velocity – 1.571 m/s** **RPM-300**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$S_d X10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-11}$ (m^3/s)
2.48	1.9	0.58	300	0.471	19.126	0.956	111.947	175.757	5.597
2.48	1.7	0.78	600	0.942	19.126	0.956	75.275	118.182	3.764
2.48	1.62	0.86	900	1.413	18.979	0.948	55.291	86.868	2.764
2.48	1.56	0.92	1200	1.884	18.832	0.941	44.369	69.745	2.218
2.48	1.5	0.98	1500	2.355	18.685	0.934	37.814	59.437	1.891

Table 4.19

Weight Fraction- 0% **Load- 20N** **Velocity – 2.094 m/s** **RPM-400**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$S_d X10^3$ (m)	F_f (N)	μ	$WrX10^{-10}$ (m^3/m)	$WsX10^{-11}$ (m^3/Nm)	$WvX10^{-10}$ (m^3/s)
3.122	2.412	0.71	300	0.628	18.979	0.949	102.779	215.152	5.139
3.122	2.222	0.9	600	1.256	18.979	0.949	65.099	136.364	3.254
3.122	2.162	0.96	900	1.884	18.979	0.948	46.298	96.969	2.315
3.122	2.102	1.02	1200	2.512	18.832	0.942	36.899	77.273	1.845
3.122	2.062	1.06	1500	3.141	18.829	0.941	30.669	64.242	1.533

Table 4.20

Weight Fraction-10% **Load- 5 N** **Velocity – 1.047 m/s** **RPM-200**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$S_d X10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-11}$ (m^3/s)
3.341	3.286	0.047	300	0.314	4.708	0.942	13.404	14.038	2.681
3.341	3.256	0.071	600	0.628	4.661	0.932	10.124	10.603	2.025
3.341	3.236	0.092	900	0.942	4.661	0.932	8.746	9.159	1.749
3.341	3.216	0.109	1200	1.256	4.661	0.932	7.771	8.139	1.554
3.341	3.206	0.12	1500	1.571	4.513	0.902	6.844	7.168	1.369

Table 4.21

Weight Fraction- 10% **Load- 5 N** **Velocity – 1.571 m/s** **RPM-300**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$S_d X10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-11}$ (m^3/s)
3.07	0.098	300	300	0.471	4.807	0.961	18.632	29.271	3.726
3.03	0.139	600	600	0.942	4.709	0.942	13.213	20.758	2.643
3	0.155	900	900	1.413	4.662	0.932	9.823	15.432	1.965
2.98	0.181	1200	1200	1.884	4.661	0.932	8.603	13.515	1.721
2.96	0.201	1500	1500	2.355	4.513	0.902	7.643	12.007	1.528

Table 4.22

Weight Fraction- 10% **Load- 5 N** **Velocity – 2.094 m/s** **RPM-400**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$S_d X10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-11}$ (m^3/s)
2.741	2.626	0.141	300	0.628	4.807	0.961	20.106	42.115	4.021
2.741	2.556	0.197	600	1.256	4.758	0.951	14.045	29.420	2.809
2.741	2.516	0.225	900	1.884	4.807	0.961	10.694	22.401	2.139
2.741	2.486	0.255	1200	2.512	4.709	0.942	9.090	19.041	1.818
2.741	2.456	0.285	1500	3.141	4.66	0.932	8.128	17.025	1.625

Table 4.23

Weight Fraction- 10% **Load- 7.5 N** **Velocity – 1.047 m/s** **RPM-200**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$S_d X10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-11}$ (m^3/s)
2.055	1.99	0.059	300	0.314	7.063	0.941	16.826	17.622	2.243
2.055	1.96	0.095	600	0.628	6.989	0.931	13.546	14.187	1.806
2.055	1.94	0.115	900	0.942	6.916	0.922	10.932	11.449	1.457
2.055	1.93	0.125	1200	1.256	6.842	0.912	8.912	9.334	1.188
2.055	1.92	0.135	1500	1.571	6.768	0.902	7.701	8.064	1.026

Table 4.24

Weight Fraction- 10% **Load- 7.5 N** **Velocity – 1.571 m/s** **RPM-300**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$S_d X10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-11}$ (m^3/s)
2.001	1.866	0.112	300	0.471	7.063	0.942	21.294	33.453	2.839
2.001	1.826	0.163	600	0.942	6.916	0.922	15.495	24.343	2.066
2.001	1.796	0.198	900	1.413	6.989	0.932	12.548	19.713	1.673
2.001	1.776	0.208	1200	1.884	6.916	0.922	9.886	15.532	1.318
2.001	1.759	0.229	1500	2.355	6.892	0.919	8.707	13.679	1.161

Table 4.25

Weight Fraction- 10% **Load-7. 5 N** **Velocity – 2.094 m/s** **RPM-400**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$S_d X10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-11}$ (m^3/s)
2.229	2.034	0.176	300	0.628	7.137	0.952	25.096	52.568	3.346
2.229	1.964	0.231	600	1.256	7.062	0.942	16.469	34.498	2.196
2.229	1.894	0.279	900	1.884	7.062	0.942	13.261	27.777	1.768
2.229	1.844	0.325	1200	2.512	6.987	0.932	11.585	24.268	1.545
2.229	1.804	0.367	1500	3.141	6.917	0.922	10.466	21.923	1.395

Table 4.26

Weight Fraction-10% **Load- 10 N** **Velocity – 1.047 m/s** **RPM-200**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$S_d X10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-11}$ (m^3/s)
3.142	3.057	0.073	300	0.314	9.417	0.942	20.818	21.804	2.082
3.142	3.017	0.109	600	0.628	9.321	0.932	15.542	1.627	1.554
3.142	2.987	0.138	900	0.942	9.202	0.920	13.118	13.739	1.312
3.142	2.967	0.154	1200	1.256	9.124	0.912	10.979	11.499	1.097
3.142	2.947	0.172	1500	1.571	9.025	0.902	9.811	10.275	0.981

Table 4.27

Weight Fraction- 10% **Load- 10 N** **Velocity – 1.571 m/s** **RPM-300**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$S_d X10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-11}$ (m^3/s)
2.372	2.237	0.135	300	0.471	9.419	0.942	25.667	40.032	2.566
2.372	2.177	0.195	600	0.942	9.222	0.922	18.537	29.157	1.854
2.372	2.137	0.235	900	1.413	9.026	0.903	14.893	23.414	1.489
2.372	2.117	0.255	1200	1.884	9.312	0.931	12.121	19.016	1.212
2.372	2.097	0.275	1500	2.355	9.361	0.936	10.457	16.412	1.045

Table 4.28

Weight Fraction- 10% **Load- 10 N** **Velocity – 2.094 m/s** **RPM-400**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$S_d X10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-10}$ (m^3/s)
2.965	2.77	0.195	300	0.628	9.517	0.952	27.805	58.2434	2.781
2.965	2.69	0.275	600	1.256	9.321	0.932	19.606	41.069	1.961
2.965	2.63	0.335	900	1.884	9.518	0.952	15.922	33.353	1.592
2.965	2.58	0.385	1200	2.512	9.518	0.952	13.724	28.748	1.372
2.965	2.543	0.422	1500	3.141	9.612	0.961	12.035	25.209	1.203

Table 4.29

Weight Fraction- 10% **Load- 15 N** **Velocity – 1.047m/s** **RPM-200**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-11}$ (m^3/s)
2.823	2.728	0.095	300	0.314	13.978	0.932	27.093	28.375	1.806
2.823	2.678	0.145	600	0.628	13.977	0.932	20.676	21.655	1.378
2.823	2.638	0.185	900	0.942	13.656	0.911	17.586	18.419	1.172
2.823	2.618	0.205	1200	1.256	13.392	0.893	14.611	15.307	0.974
2.823	2.598	0.225	1500	1.571	13.392	0.893	12.833	13.441	0.855

Table 4.30

Weight Fraction- 10% **Load- 15 N** **Velocity – 1.571 m/s** **RPM-300**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-10}$ (m^3/s)
1.606	1.441	0.165	300	0.471	13.978	0.932	31.371	49.283	2.091
1.606	1.361	0.245	600	0.942	13.998	0.933	23.291	36.589	1.552
1.606	1.311	0.295	900	1.413	13.481	0.898	18.695	29.371	1.246
1.606	1.271	0.335	1200	1.884	13.482	0.898	15.922	25.014	1.061
1.606	1.243	0.363	1500	2.355	13.586	0.905	13.803	21.684	.921

Table 4.31

Weight Fraction- 10% **Load- 15 N** **Velocity – 2.094 m/s** **RPM-400**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-11}$ (m^3/s)
1.471	1.216	0.255	300	0.628	14.127	0.9418	36.3613	76.165	2.424
1.471	1.119	0.352	600	1.256	13.98	0.932	25.0965	52.568	1.673
1.471	1.046	0.425	900	1.884	13.981	0.93206	20.2007	42.313	1.346
1.471	0.996	0.475	1200	2.512	13.537	0.90246	16.933	35.468	1.128
1.471	0.956	0.515	1500	3.141	13.392	0.8928	14.6871	30.764	0.979

Table 4.32

Weight Fraction- 10% **Load- 20 N** **Velocity – 1.047 m/s** **RPM-200**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-11}$ (m^3/s)
1.735	1.637	0.098	300	0.314	18.712	0.935	27.948	29.271	1.397
1.735	1.567	0.168	600	0.628	18.615	0.931	23.951	25.089	1.197
1.735	1.527	0.208	900	0.942	18.915	0.945	19.773	20.708	0.988
1.735	1.507	0.228	1200	1.256	18.915	0.945	16.255	17.025	0.812
1.735	1.497	0.238	1500	1.571	18.925	0.946	13.575	14.217	0.678

Table 4.33

Weight Fraction- 10% **Load- 20 N** **Velocity – 1.571 m/s** **RPM-300**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WvX10^{-11}$ (m^3/s)
2.187	2.015	0.172	300	0.471	19.231	0.961	32.701	51.374	1.635
2.187	1.935	0.252	600	0.942	19.234	0.961	23.955	37.634	1.197
2.187	1.885	0.302	900	1.413	19.236	0.961	19.139	30.067	0.956
2.187	1.845	0.342	1200	1.884	19.236	0.961	16.255	25.537	0.812
2.187	1.835	0.352	1500	2.355	19.237	0.961	13.384	21.027	0.669

Table 4.34

Weight Fraction- 10% **Load- 20 N** **Velocity – 2.094 m/s** **RPM-400**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-11}$ (m^3/s)
2.272	2	0.272	300	0.628	19.351	0.872	81.242	81.242	1.939
2.272	1.9	0.372	600	1.256	19.352	0.752	55.555	55.556	1.326
2.272	1.84	0.432	900	1.884	19.352	0.702	43.011	43.011	1.026
2.272	1.79	0.482	1200	2.512	19.421	0.69	35.992	35.991	0.8591
2.272	1.75	0.522	1500	3.141	19.431	0.676	31.183	31.182	0.744

Table 4.35

Weight Fraction- 20% **Load- 5 N** **Velocity – 1.047 m/s** **RPM-200**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-10}$ (m^3/m)	$WsX10^{-11}$ (m^3/Nm)	$WvX10^{-10}$ (m^3/s)
3.38	3.325	0.038	300	0.314	4.807	0.961	10.562	11.062	2.112
3.38	3.305	0.065	600	0.628	4.808	0.961	9.0338	9.461	1.806
3.38	3.285	0.087	900	0.942	4.758	0.951	8.061	8.442	1.612
3.38	3.275	0.099	1200	1.256	4.708	0.941	6.879	7.205	1.375
3.38	3.265	0.109	1500	1.571	4.612	0.922	6.059	6.346	1.211

Table 4.36

Weight Fraction- 20% **Load- 5 N** **Velocity – 1.571 m/s** **RPM-300**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-10}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-10}$ (m^3/s)
2.524	2.439	0.085	300	0.471	4.857	0.971	15.751	24.745	3.151
2.524	2.399	0.125	600	0.942	4.804	0.961	11.582	18.195	2.316
2.524	2.379	0.145	900	1.413	4.756	0.951	8.956	14.071	1.791
2.524	2.359	0.165	1200	1.884	4.661	0.932	7.644	12.008	1.528
2.524	2.339	0.185	1500	2.355	4.661	0.932	6.856	10.771	1.371

Table 4.37

Weight Fraction- 20% **Load- 5 N** **Velocity – 2.094 m/s** **RPM-400**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-11}$ (m^3/s)
2.273	2.148	0.121	300	0.628	4.857	0.971	16.811	35.225	3.363
2.273	2.108	0.179	600	1.256	4.804	0.961	12.432	26.055	2.4877
2.273	2.078	0.195	900	1.884	4.756	0.951	09.033	18.923	1.806
2.273	2.048	0.228	1200	2.512	4.711	0.942	07.921	16.594	1.584
2.273	2.038	0.252	1500	3.141	4.661	0.932	07.016	14.672	1.403

Table 4.38

Weight Fraction-20% **Load- 7.5 N** **Velocity – 1.047 m/s** **RPM-200**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-11}$ (m^3/s)
1.702	1.651	0.051	300	0.314	7.211	0.961	14.176	14.847	1.891
1.702	1.617	0.085	600	0.628	7.196	0.959	11.813	12.372	1.575
1.702	1.597	0.105	900	0.942	7.063	0.941	09.728	10.189	1.297
1.702	1.587	0.115	1200	1.256	6.981	0.931	07.991	8.369	1.065
1.702	1.577	0.125	1500	1.571	6.842	0.911	06.949	7.278	0.9265

Table 4.39

Weight Fraction- 20% **Load- 7.5 N** **Velocity – 1.571m/s** **RPM-300**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-10}$ (m^3/m)	$WsX10^{-11}$ (m^3/Nm)	$WvX10^{-10}$ (m^3/s)
1.438	1.343	0.095	300	0.471	7.137	0.951	17.604	27.656	2.347
1.438	1.293	0.145	600	0.942	7.121	0.949	13.434	21.106	1.791
1.438	1.273	0.165	900	1.413	7.101	0.946	10.192	16.012	1.358
1.438	1.253	0.185	1200	1.884	6.986	0.931	08.571	13.464	1.142
1.438	1.233	0.205	1500	2.355	6.981	0.931	07.597	11.936	1.013

Table 4.40

Weight Fraction- 20% **Load- 7.5 N** **Velocity – 2.094 m/s** **RPM-400**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WsX10^{-11}$ (m^3/Nm)	$WvX10^{-11}$ (m^3/s)
1.719	1.564	0.155	300	0.628	7.211	0.961	21.5422	45.123	2.872
1.719	1.504	0.215	600	1.256	7.112	0.948	14.9406	31.295	1.992
1.719	1.464	0.255	900	1.884	7.109	0.947	11.8135	24.745	1.575
1.719	1.424	0.295	1200	2.512	7.091	0.945	10.2499	21.470	1.366
1.719	1.384	0.335	1500	3.141	6.981	0.931	9.31179	19.501	1.241

Table 4.41

Weight Fraction- 20% **Load- 10 N** **Velocity – 1.0471m/s** **RPM-200**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-10}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-10}$ (m^3/s)
2.896	2.831	0.065	300	0.314	9.615	0.961	18.067	18.923	1.806
2.896	2.801	0.095	600	0.628	9.418	0.942	13.203	13.828	1.321
2.896	2.781	0.115	900	0.942	9.408	0.941	10.655	11.159	1.065
2.896	2.761	0.135	1200	1.256	9.222	0.922	09.381	09.825	0.938
2.896	2.751	0.145	1500	1.571	9.025	0.902	08.061	08.442	0.806

Table 4.42

Weight Fraction- 20% **Load- 10 N** **Velocity – 1.571m/s** **RPM-300**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-11}$ (m^3/s)
2.398	2.293	0.105	300	0.471	9.415	0.941	19.457	30.567	1.945
2.398	2.253	0.145	600	0.942	9.41	0.941	13.435	21.106	1.343
2.398	2.233	0.165	900	1.413	9.321	0.932	10.192	16.011	1.019
2.398	2.203	0.195	1200	1.884	9.221	0.922	9.033	14.192	0.903
2.398	2.183	0.215	1500	2.355	9.123	0.912	7.968	12.518	0.796

Table 4.43

Weight Fraction- 20% **Load- 10 N** **Velocity – 2..094m/s** **RPM-400**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	SdX10^3 (m)	F_f (N)	μ	WrX10^{-11} (m^3/m)	WsX10^{-11} (m^3/Nm)	WvX10^{-11} (m^3/s)
2.02	1.855	0.165	300	0.628	9.517	0.952	22.932	48.035	2.293
2.02	1.795	0.225	600	1.256	9.501	0.951	15.635	32.751	1.563
2.02	1.745	0.275	900	1.885	9.409	0.941	12.741	26.686	1.274
2.02	1.705	0.315	1200	2.513	9.389	0.939	10.945	22.925	1.094
2.02	1.675	0.345	1500	3.142	9.381	0.938	9.589	20.087	0.958

Table 4.44

Weight Fraction- 20% **Load- 15 N** **Velocity – 1.0471m/s** **RPM-200**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	SdX10^3 (m)	F_f (N)	μ	WrX10^{-11} (m^3/m)	WvX10^{-11} (m^3/Nm)	WsX10^{-11} (m^3/s)
1.913	1.828	0.085	300	0.314	14.251	0.951	23.626	24.745	1.575
1.913	1.798	0.115	600	0.628	14.241	0.949	15.982	16.739	1.065
1.913	1.778	0.135	900	0.942	14.139	0.942	12.508	13.100	0.833
1.913	1.768	0.145	1200	1.256	14.138	0.942	10.076	10.553	0.671
1.913	1.748	0.165	1500	1.571	14.121	0.941	09.172	09.606	0.611

Table 4.45

Weight Fraction- 20% **Load- 15 N** **Velocity – 1.571m/s** **RPM-300**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-11}$ (m^3/s)
2.345	2.21	0.131	300	0.471	14.431	0.962	242.755	38.136	1.618
2.345	2.12	0.225	600	0.942	14.421	0.961	20.8473	32.751	1.389
2.345	2.06	0.285	900	1.413	14.412	0.961	17.6044	27.656	1.173
2.345	2.04	0.304	1200	1.884	14.411	0.961	14.0835	22.125	0.938
2.345	2.01	0.335	1500	2.355	14.301	0.953	12.4157	19.505	0.827

Table 4.46

Weight Fraction- 20% **Load- 15 N** **Velocity – 2.094m/s** **RPM-400**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-10}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-10}$ (m^3/s)
3.052	2.835	0.217	300	0.6284	14.441	0.962	30.159	63.173	2.010
3.052	2.711	0.341	600	1.2568	14.431	0.962	23.696	49.636	1.579
3.052	2.65	0.402	900	1.8852	14.42	0.961	18.623	39.010	1.241
3.052	2.592	0.46	1200	2.5136	13.986	0.932	15.982	33.478	1.065
3.052	2.551	0.501	1500	3.142	13.981	0.932	13.926	29.170	0.928

Table 4.47

Weight Fraction- 20% **Load- 20 N** **Velocity – 1.0471m/s** **RPM-200**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-11}$ (m^3/s)
2.007	1.922	0.085	300	0.314	19.219	0.961	23.626	24.745	1.181
2.007	1.872	0.135	600	0.628	19.21	0.961	18.762	19.650	0.938
2.007	1.852	0.155	900	0.942	19.111	0.955	14.361	15.041	0.718
2.007	1.842	0.165	1200	1.256	19.108	0.955	11.466	12.008	0.573
2.007	1.832	0.175	1500	1.571	18.896	0.945	09.728	10.189	0.486

Table 4.48

Weight Fraction- 20% **Load- 20 N** **Velocity – 1.571m/s** **RPM-300**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-10}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-10}$ (m^3/s)
1.589	1.424	0.165	300	0.471	19.345	0.967	30.576	48.034	1.528
1.589	1.356	0.233	600	0.942	19.332	0.966	21.588	33.915	1.079
1.589	1.306	0.283	900	1.413	19.311	0.965	17.480	27.462	0.874
1.589	1.28	0.309	1200	1.884	19.101	0.955	14.315	22.489	0.715
1.589	1.242	0.347	1500	2.355	18.986	0.949	12.861	20.203	0.643

Table 4.49

Weight Fraction- 20% **Load- 20 N** **Velocity – 2.094m/s** **RPM-400**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	SdX10^3 (m)	F_f (N)	μ	WrX10^{-11} (m^3/m)	WvX10^{-11} (m^3/Nm)	WsX10^{-11} (m^3/s)
1.715	1.43	0.285	300	0.628	19.431	0.971	39.609	82.969	1.981
1.715	1.37	0.345	600	1.256	19.331	0.966	23.974	50.218	1.198
1.715	1.336	0.379	900	1.885	19.325	0.966	17.558	36.778	0.877
1.715	1.32	0.395	1200	2.513	19.215	0.961	13.724	28.748	0.686
1.715	1.304	0.411	1500	3.142	19.016	0.951	11.424	23.931	0.571

Table 4.50

Weight Fraction- 30% **Load- 5 N** **Velocity – 1.0471m/s** **RPM-200**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	SdX10^3 (m)	F_f (N)	μ	WrX10^{-11} (m^3/m)	WvX10^{-11} (m^3/Nm)	WsX10^{-11} (m^3/s)
2.819	2.754	0.065	300	0.3142	4.806	0.961	18.178	19.039	3.635
2.819	2.724	0.095	600	0.6284	4.801	0.962	13.284	13.913	2.656
2.819	2.704	0.115	900	0.9426	4.796	0.959	10.721	11.228	2.144
2.819	2.694	0.139	1200	1.2568	4.792	0.958	09.718	10.178	1.943
2.819	2.674	0.155	1500	1.571	4.623	0.924	08.669	09.081	1.733

Table 4.51

Weight Fraction- 30% **Load- 5 N** **Velocity – 1.571m/s** **RPM-300**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-10}$ (m^3/m)	$WsX10^{-11}$ (m^3/Nm)	$WvX10^{-10}$ (m^3/s)
1.98	1.865	0.129	300	0.4713	4.812	0.9624	24.051	37.785	4.811
1.98	1.825	0.179	600	0.9426	4.802	0.9604	16.687	26.215	3.337
1.98	1.805	0.201	900	1.4139	4.791	0.9582	12.492	19.625	2.498
1.98	1.775	0.223	1200	1.8852	4.711	0.942	10.394	16.329	2.078
1.98	1.745	0.252	1500	2.3565	4.623	0.9246	09.397	14.762	1.879

Table 4.52

Weight Fraction- 30% **Load- 5 N** **Velocity – 2.094 m/s** **RPM-400**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-10}$ (m^3/m)	$WsX10^{-11}$ (m^3/Nm)	$WvX10^{-10}$ (m^3/s)
2.629	2.432	0.197	300	0.6284	4.861	0.972	27.547	57.703	5.509
2.629	2.376	0.253	600	1.2568	4.796	0.959	17.689	37.053	3.537
2.629	2.342	0.287	900	1.8852	4.796	0.959	13.377	28.021	2.675
2.629	2.323	0.306	1200	2.5136	4.623	0.924	10.697	22.407	2.139
2.629	2.282	0.347	1500	3.1421	4.616	0.923	09.704	20.328	1.941

Table 4.53

Weight Fraction- 30% **Load- 7.5 N** **Velocity – 1.0471m/s** **RPM-200**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-10}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WvX10^{-10}$ (m^3/s)
2.856	2.781	0.075	300	0.3142	7.211	0.961	20.975	21.968	2.796
2.856	2.741	0.115	600	0.6284	7.064	0.941	16.081	16.842	2.144
2.856	2.721	0.135	900	0.9426	7.011	0.934	12.585	13.181	1.678
2.856	2.701	0.155	1200	1.2568	6.986	0.931	10.837	11.351	1.444
2.856	2.691	0.165	1500	1.571	6.981	0.931	09.229	9.666	1.231

Table 4.54

Weight Fraction- 30% **Load- 7.5 N** **Velocity – 1.571m/s** **RPM-300**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-10}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-10}$ (m^3/s)
1.624	1.499	0.163	300	0.471	7.137	0.951	30.391	47.744	4.052
1.624	1.429	0.205	600	0.942	7.137	0.951	19.111	30.023	2.548
1.624	1.389	0.226	900	1.413	7.063	0.941	14.045	22.066	1.872
1.624	1.369	0.258	1200	1.884	6.988	0.931	12.026	18.892	1.603
1.624	1.349	0.271	1500	2.355	6.965	0.928	10.105	15.875	1.347

Table 4.55

Weight Fraction- 30% **Load- 7.5 N** **Velocity –2.094m/s** **RPM-400**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-10}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-10}$ (m^3/s)
3.518	3.313	0.278	300	0.628	7.116	0.948	38.874	81.429	5.183
3.518	3.223	0.351	600	1.256	7.111	0.948	24.541	51.406	3.272
3.518	3.143	0.395	900	1.885	7.011	0.934	18.411	38.566	2.454
3.518	3.103	0.425	1200	2.513	6.989	0.932	14.857	31.121	1.981
3.518	3.063	0.477	1500	3.142	6.988	0.932	13.341	27.943	1.778

Table 4.56

Weight Fraction- 30% **Load- 10 N** **Velocity – 1.0471m/s** **RPM-200**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-11}$ (m^3/s)
3.235	3.15	0.092	300	0.314	9.718	0.971	25.731	26.947	2.573
3.235	3.11	0.135	600	0.628	9.616	0.961	18.878	19.771	1.887
3.235	3.07	0.165	900	0.942	9.601	0.960	15.382	16.111	1.538
3.235	3.05	0.191	1200	1.256	9.556	0.955	13.354	13.986	1.335
3.235	3.03	0.217	1500	1.571	9.554	0.955	12.137	12.712	1.213

Table 4.57

Weight Fraction- 30% **Load- 10N** **Velocity – 1.571m/s** **RPM-300**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-11}$ (m^3/s)
1.192	1.047	0.145	300	0.471	9.416	0.941	27.035	42.472	2.703
1.192	0.977	0.215	600	0.942	9.411	0.941	20.043	31.488	2.004
1.192	0.937	0.255	900	1.413	9.333	0.933	15.848	24.897	1.584
1.192	0.907	0.285	1200	1.884	9.222	0.922	13.284	20.869	1.328
1.192	0.877	0.315	1500	2.355	9.122	0.912	11.746	18.453	1.174

Table 4.58

Weight Fraction- 30% **Load- 10 N** **Velocity – 2.094m/s** **RPM-400**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-10}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-10}$ (m^3/s)
1.29	0.995	0.295	300	0.6284	9.516	0.951	41.2519	86.408	4.125
1.29	0.905	0.385	600	1.2568	9.511	0.951	26.9186	56.385	2.691
1.29	0.865	0.425	900	1.8852	9.408	0.941	19.8102	41.495	1.981
1.29	0.815	0.475	1200	2.5136	9.388	0.938	16.6056	34.783	1.661
1.29	0.795	0.495	1500	3.142	9.387	0.938	1.38438	28.899	1.384

Table 4.59

Weight Fraction- 30% **Load- 15 N** **Velocity – 1.0471m/s** **RPM-200**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-11}$ (m^3/s)
3.235	3.13	0.105	300	0.3142	13.899	0.926	29.365	30.755	1.957
3.235	3.08	0.155	600	0.6284	13.916	0.927	21.674	22.701	1.444
3.235	3.03	0.205	900	0.9426	13.886	0.925	19.111	20.015	1.274
3.235	3	0.235	1200	1.2568	13.885	0.925	16.431	17.208	1.095
3.235	2.98	0.255	1500	1.571	13.716	0.914	14.263	14.938	0.951

Table 4.60

Weight Fraction- 30% **Load- 15 N** **Velocity – 1.571m/s** **RPM-300**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-11}$ (m^3/s)
2.57	2.395	0.175	300	0.471	14.661	0.977	32.628	51.259	2.175
2.57	2.304	0.266	600	0.942	14.421	0.961	24.797	38.957	1.653
2.57	2.255	0.315	900	1.413	14.419	0.961	19.577	30.755	1.305
2.57	2.205	0.365	1200	1.884	14.41	0.961	17.013	26.728	1.134
2.57	2.165	0.405	1500	2.355	14.301	0.953	15.102	23.725	1.006

Table 4.61

Weight Fraction- 30% **Load- 15 N** **Velocity – 2.094m/s** **RPM-400**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-10}$ (m^3/m)	$WsX10^{-11}$ (m^3/Nm)	$WvX10^{-10}$ (m^3/s)
1.929	1.614	0.315	300	0.6284	14.215	0.947	44.049	92.267	2.937
1.929	1.494	0.435	600	1.2568	14.214	0.947	30.415	63.708	2.027
1.929	1.434	0.495	900	1.8852	14.116	0.941	23.073	48.330	1.538
1.929	1.384	0.545	1200	2.5136	14.001	0.933	19.053	39.909	1.271
1.929	1.354	0.575	1500	3.142	13.989	0.932	16.081	33.685	1.072

Table 4.62

Weight Fraction- 30% **Load- 20 N** **Velocity – 1.0471m/s** **RPM-200**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-10}$ (m^3/m)	$WsX10^{-11}$ (m^3/Nm)	$WvX10^{-10}$ (m^3/s)
2.19	2.084	0.106	300	0.3142	19.001	0.950	29.645	31.049	1.482
2.19	2.007	0.183	600	0.6284	18.885	0.944	25.591	26.801	1.279
2.19	1.955	0.235	900	0.9426	18.804	0.940	21.907	22.945	1.095
2.19	1.932	0.258	1200	1.2568	18.804	0.940	18.039	18.893	0.902
2.19	1.903	0.287	1500	1.571	18.706	0.935	16.053	16.813	0.803

Table 4.63

Weight Fraction- 30% **Load- 20 N** **Velocity – 1.571m/s** **RPM-300**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-10}$ (m^3/s)
1.567	1.352	0.215	300	0.471	19.126	0.956	40.086	62.976	2.004
1.567	1.242	0.325	600	0.942	19.121	0.956	30.298	47.598	1.515
1.567	1.186	0.381	900	1.413	19.105	0.955	23.679	37.199	1.184
1.567	1.14	0.427	1200	1.884	19.059	0.953	19.903	31.268	0.995
1.567	1.128	0.439	1500	2.355	18.989	0.949	16.371	25.717	0.818

Table 4.64

Weight Fraction- 30% **Load- 20 N** **Velocity – 2.094m/s** **RPM-400**

m_1 (gm.)	m_2 (gm.)	Δm (gm.)	t (sec)	$SdX10^3$ (m)	F_f (N)	μ	$WrX10^{-11}$ (m^3/m)	$WvX10^{-11}$ (m^3/Nm)	$WsX10^{-10}$ (m^3/s)
2.062	1.711	0.351	300	0.628	19.216	0.961	49.082	102.812	2.454
2.062	1.544	0.518	600	1.257	19.117	0.956	36.218	075.864	1.811
2.062	1.441	0.621	900	1.885	19.217	0.961	28.946	060.633	1.447
2.062	1.424	0.638	1200	2.514	19.116	0.956	22.304	046.719	1.115
2.062	1.403	0.659	1500	3.142	19.012	0.951	18.431	038.605	0.922

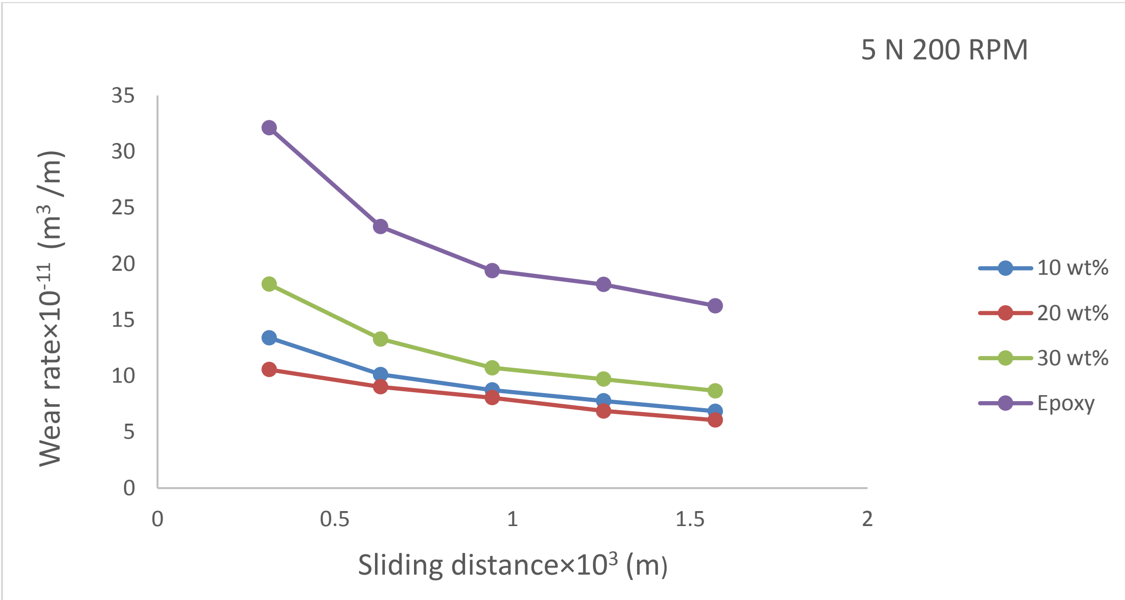


Figure-4.6 (Represents the Variation of Wear with Sliding distance at 5N 200 RPM)

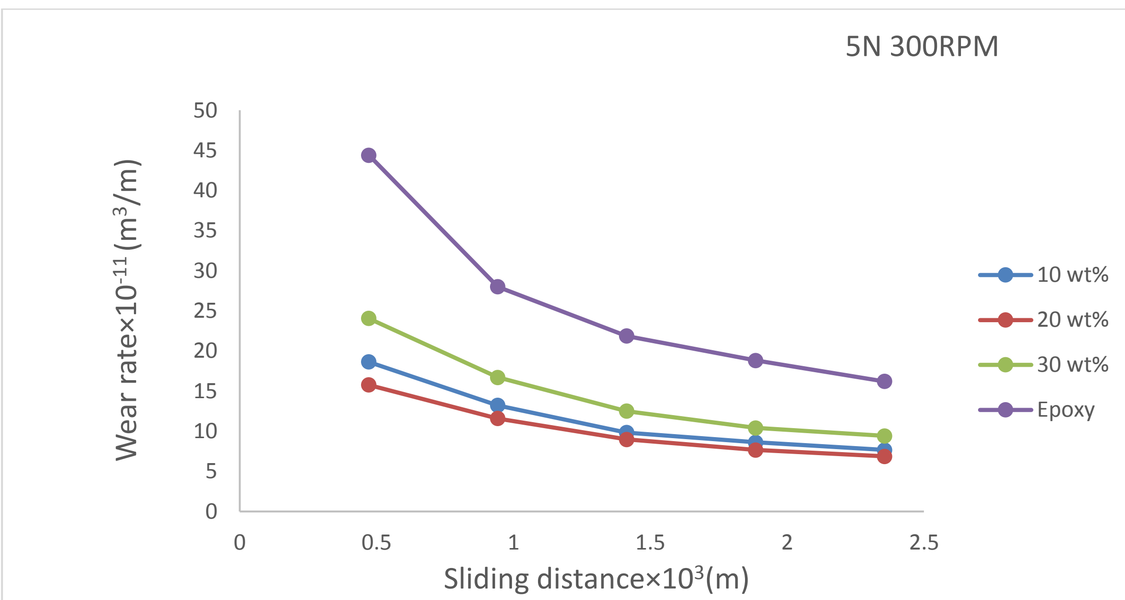


Figure-4.7 (Represents the Variation of Wear with Sliding distance at 5N 300 RPM)

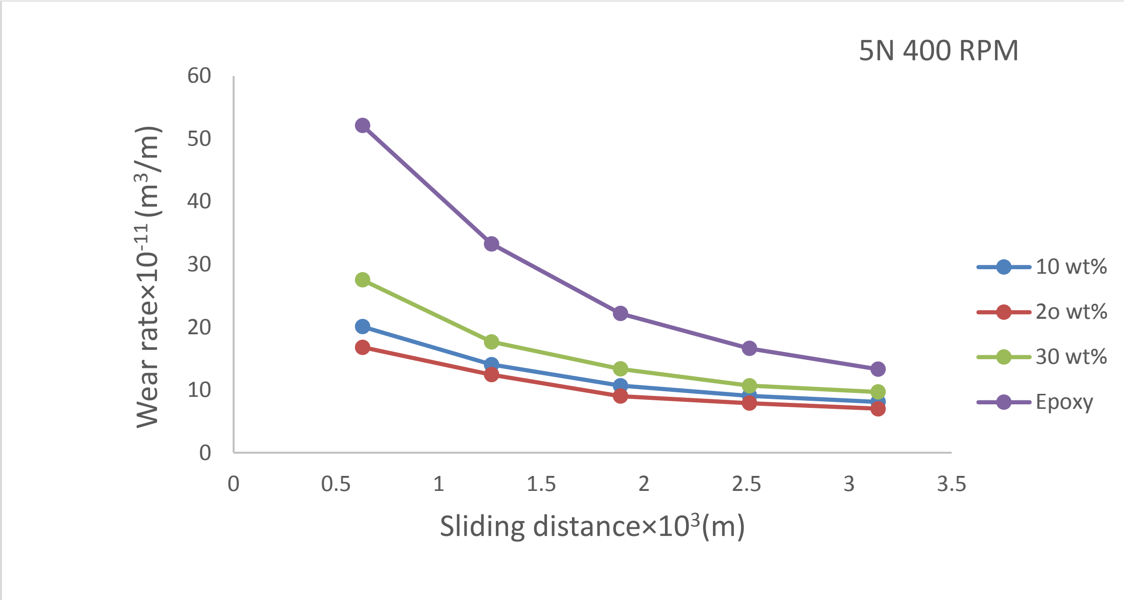


Figure-4.8 (Represents the Variation of Wear with Sliding distance at 5N 400 RPM)

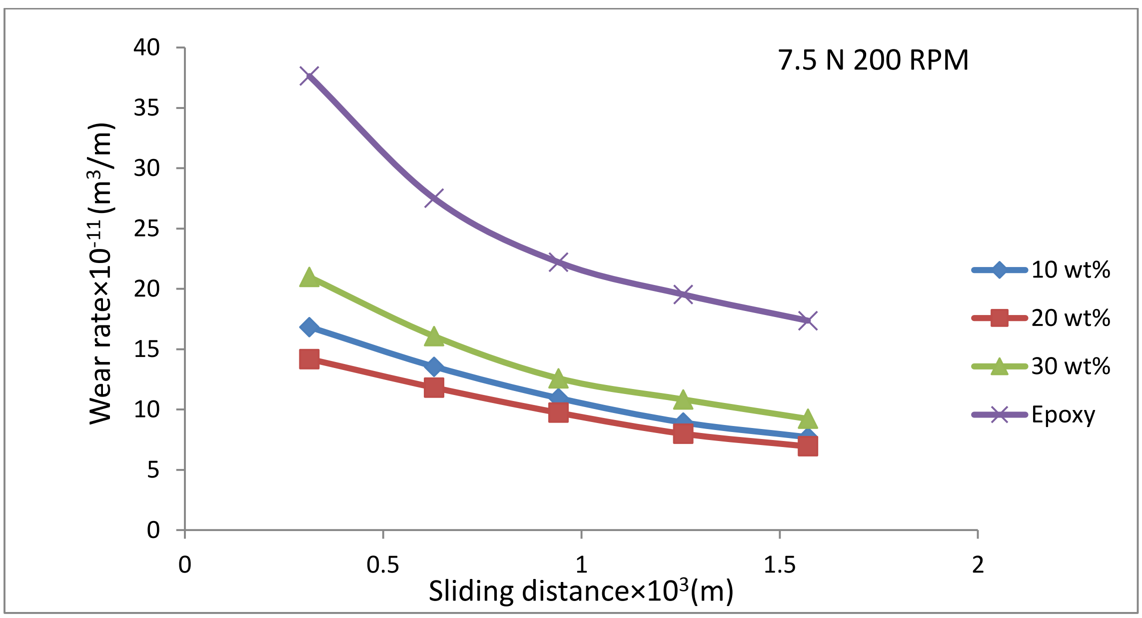


Figure-4.9 (Represents the Variation of Wear with Sliding distance at 7.5N 200 RPM)

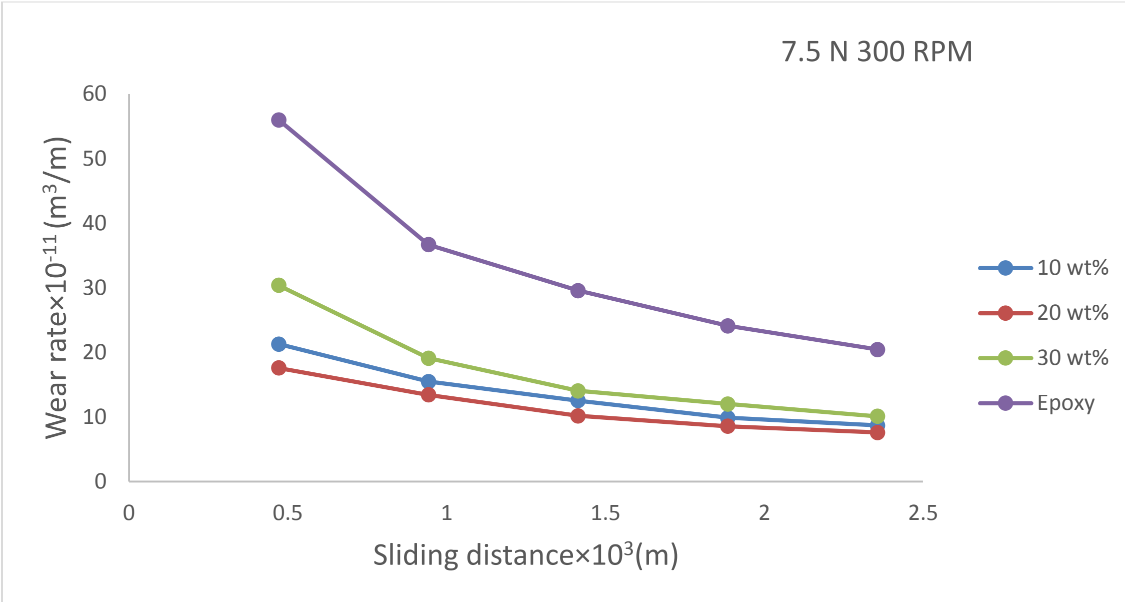


Figure-4.10 (Represents the Variation of Wear with Sliding distance at 7.5N 300 RPM)

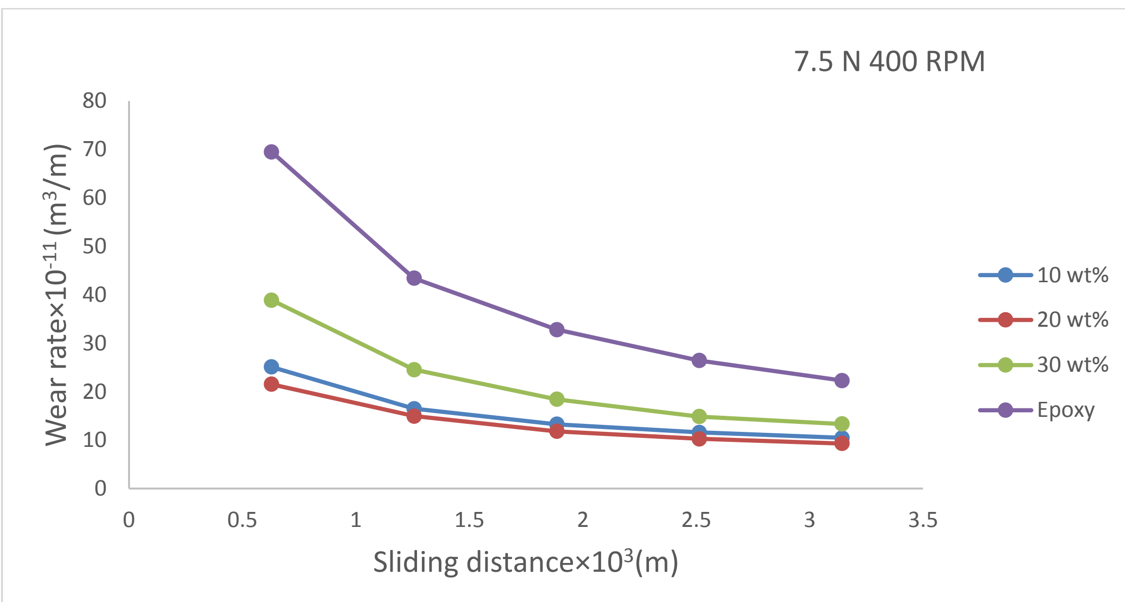


Figure-4.11 (Represents the Variation of Wear with Sliding distance at 7.5N 400 RPM)

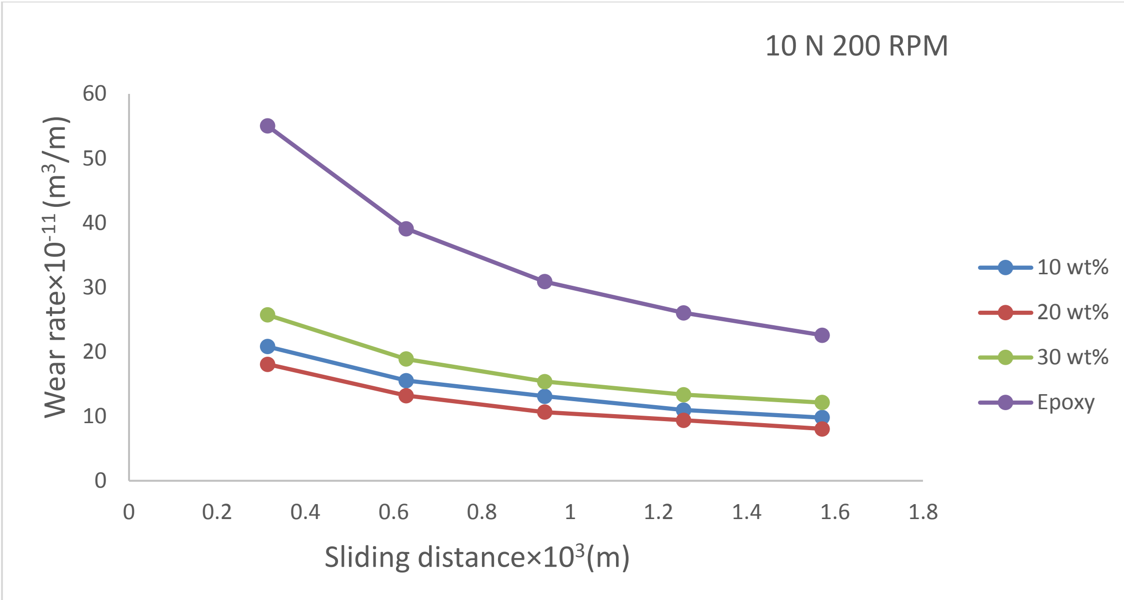


Figure-4.12 (Represents the Variation of Wear with Sliding distance at 10N 200 RPM)

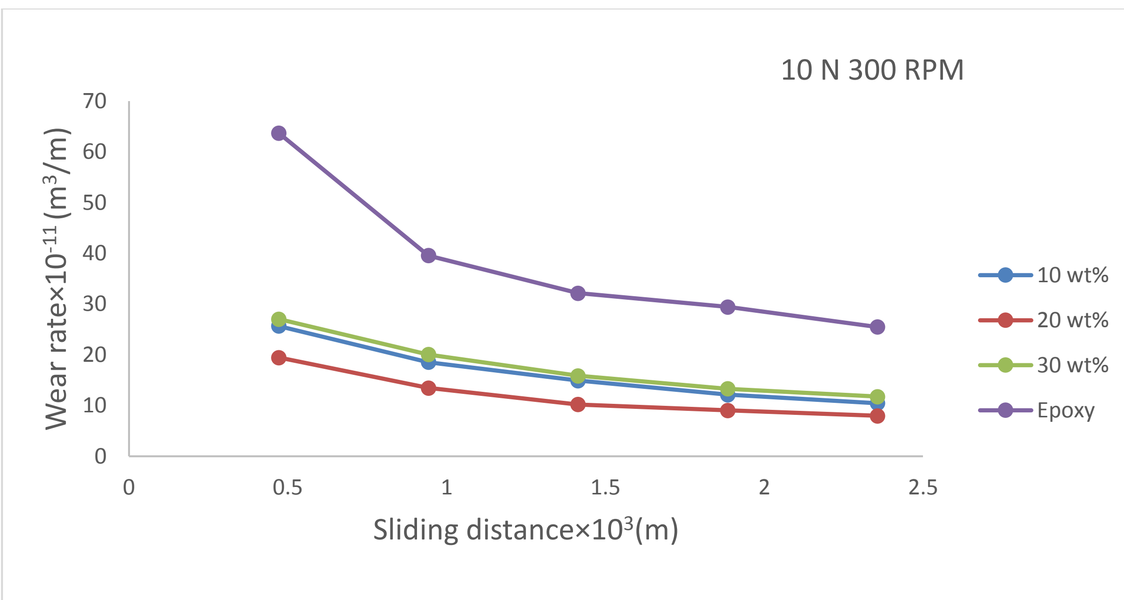


Figure-4.13 (Represents the Variation of Wear with Sliding distance at 10N 200 RPM)

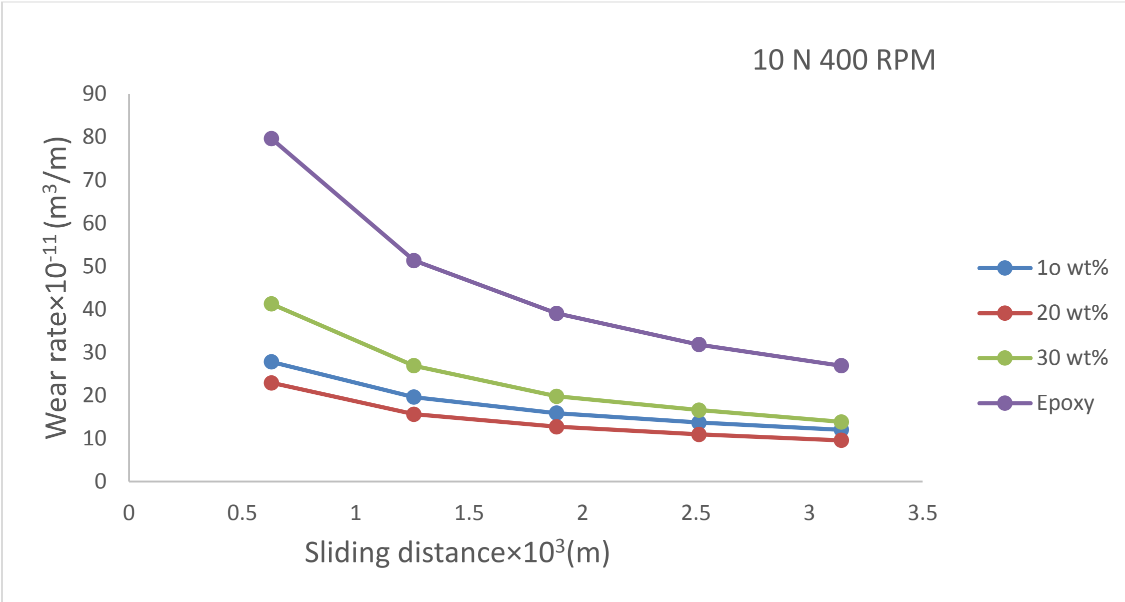


Figure-4.14 (Represents the Variation of Wear with Sliding distance at 10N 400 RPM)

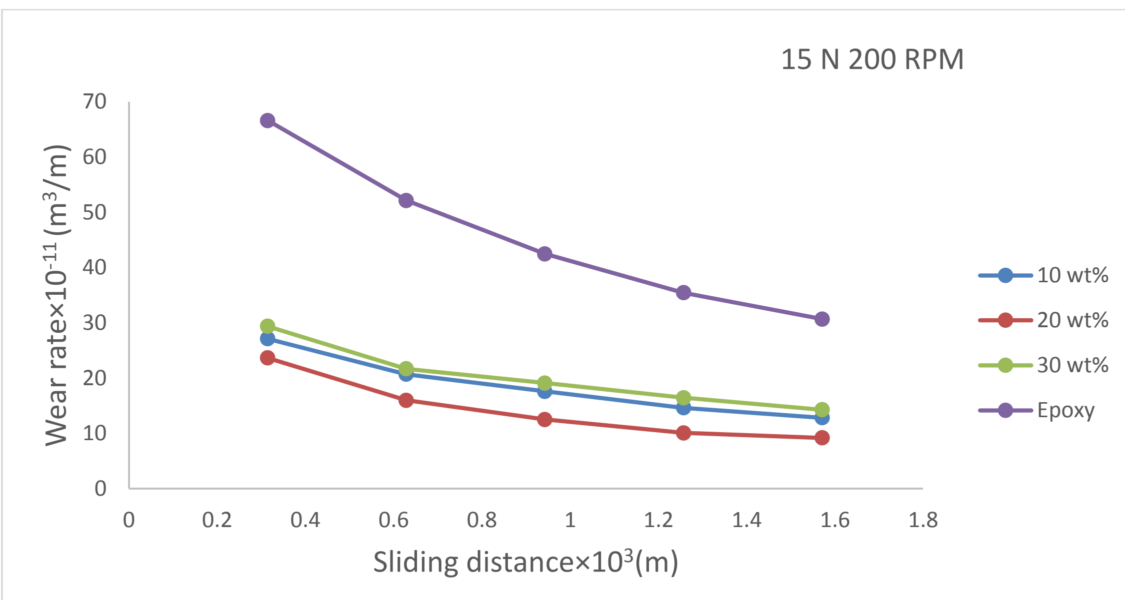


Figure-4.15 (Represents the Variation of Wear with Sliding distance at 15N 200 RPM)

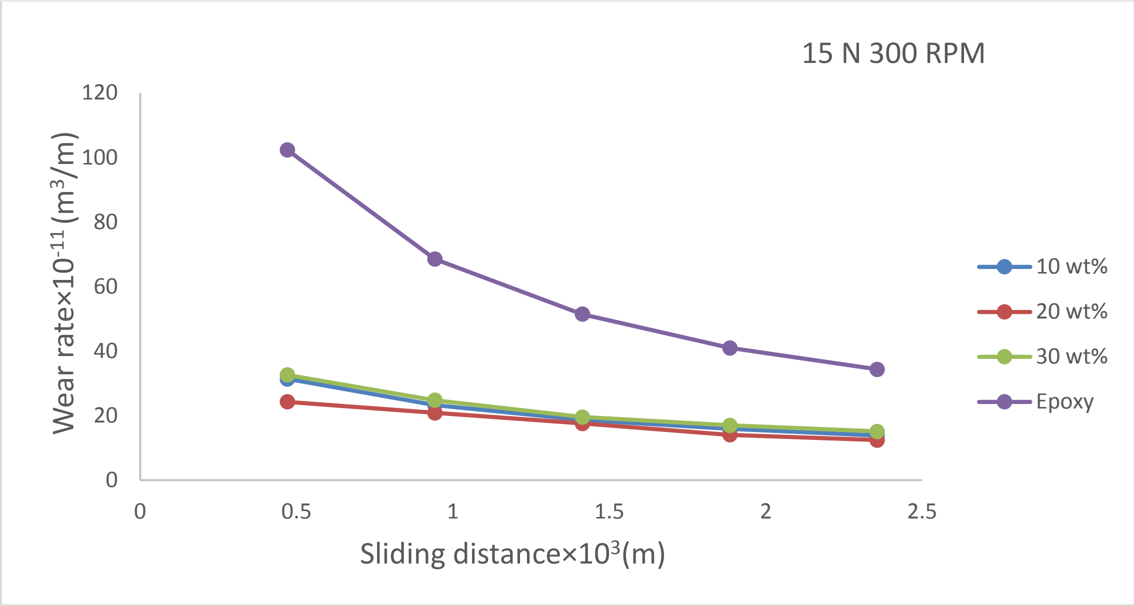


Figure-4.16 (Represents the Variation of Wear with Sliding distance at 15N 400 RPM)

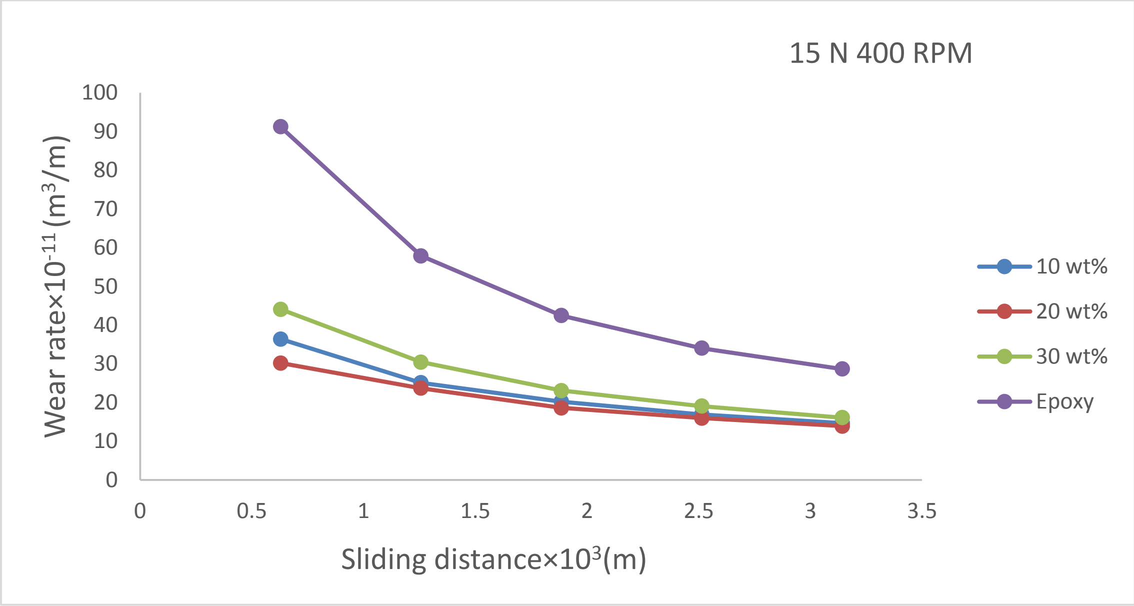


Figure-4.17 (Represents the Variation of Wear with Sliding distance at 15N 400 RPM)

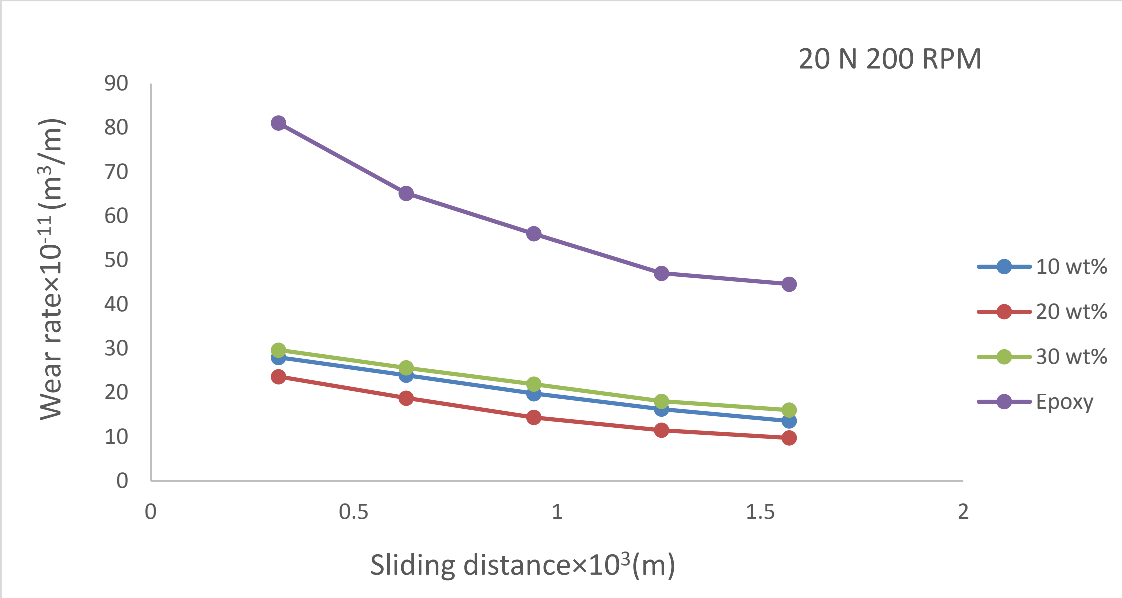


Figure-4.18 (Represents the Variation of Wear with Sliding distance at 20N 200 RPM)

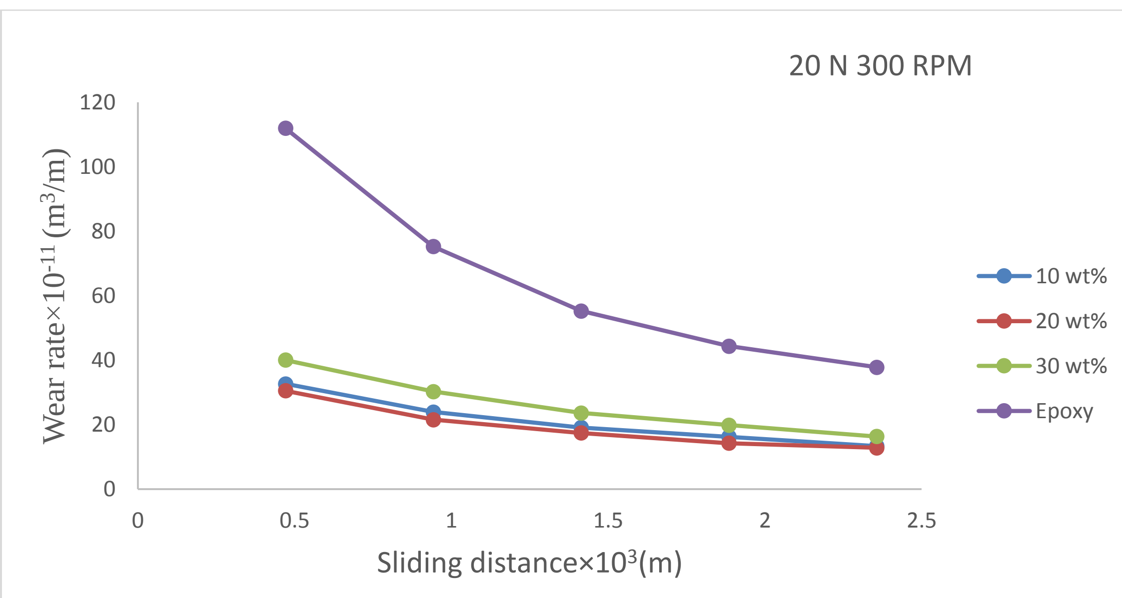


Figure-4.19 (Represents the Variation of Wear with Sliding distance at20N 300 RPM)

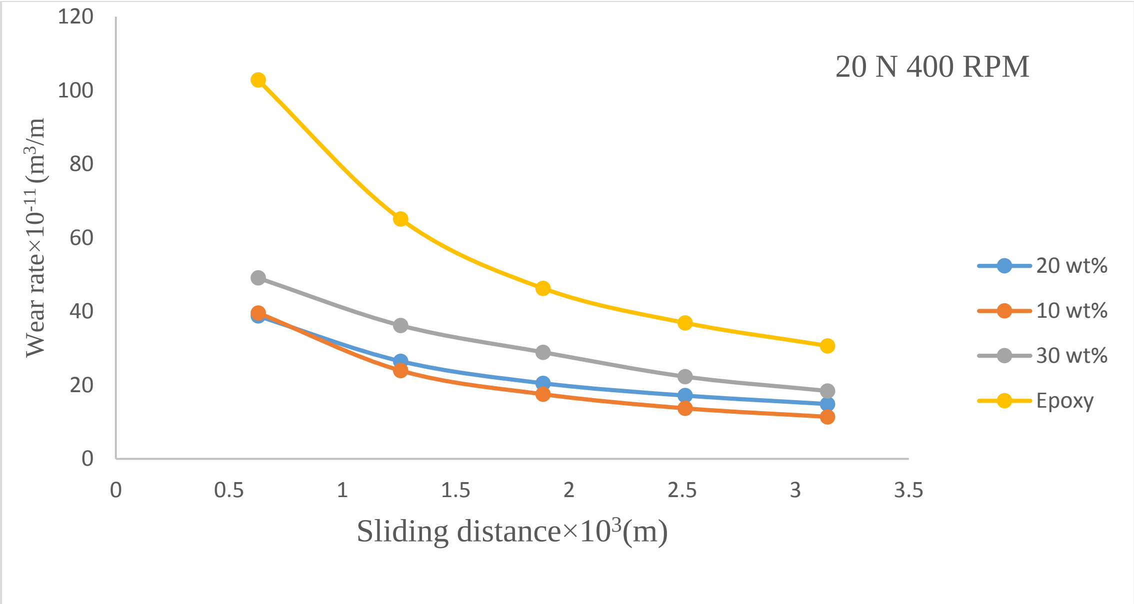


Figure-4.19 (Represents the Variation of Wear with Sliding distance at 20N 400 RPM)

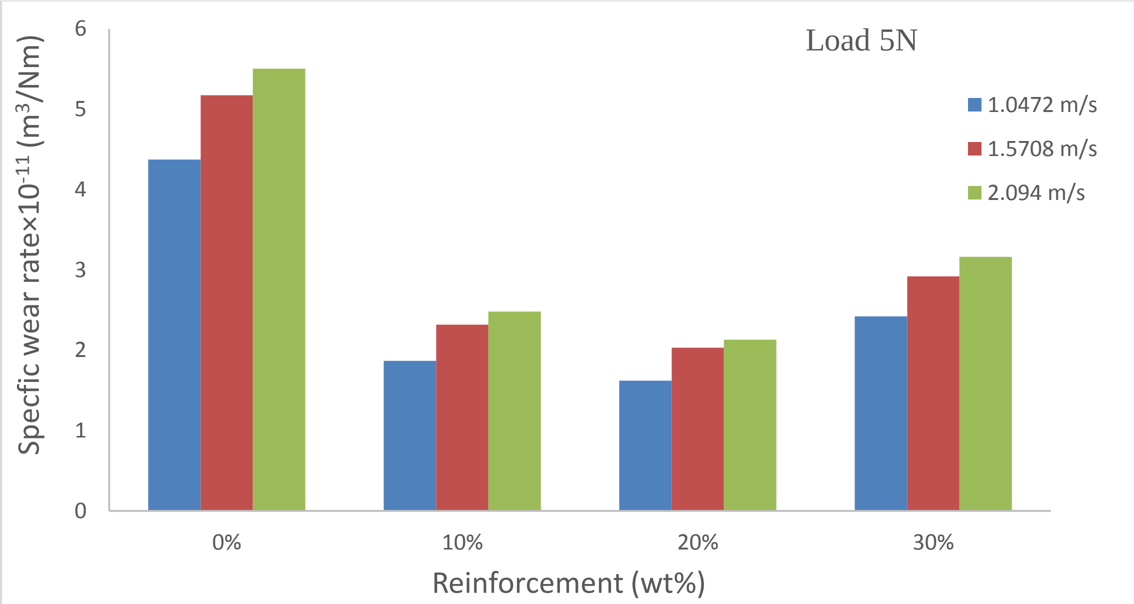


Figure-4.21 (Specific wear rate with weight fraction for Orange peel epoxy composite at 5 N)

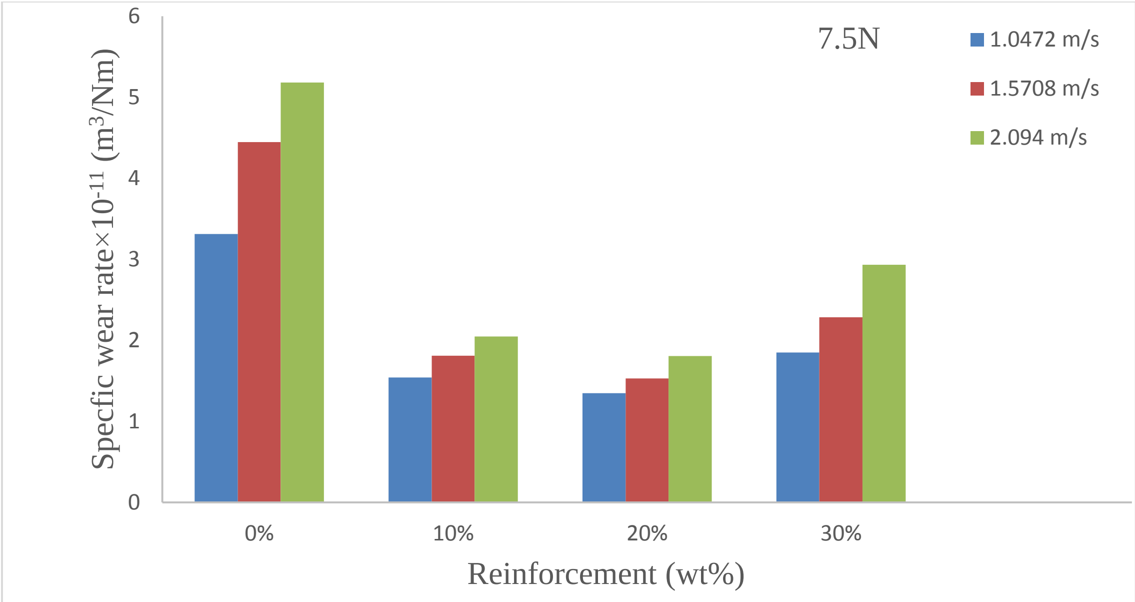


Figure-4.22 (Specific wear rate with weight fraction for Orange peel epoxy composite at 7.5 N)

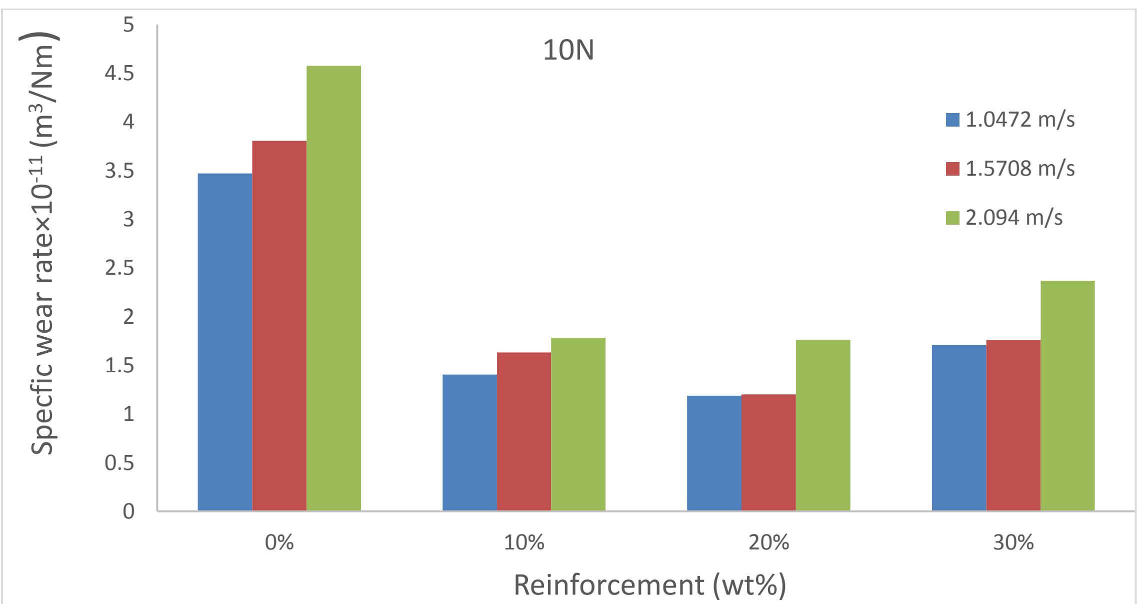


Figure-4.23 (Specific wear rate with weight fraction for Orange peel epoxy composite at 10 N)

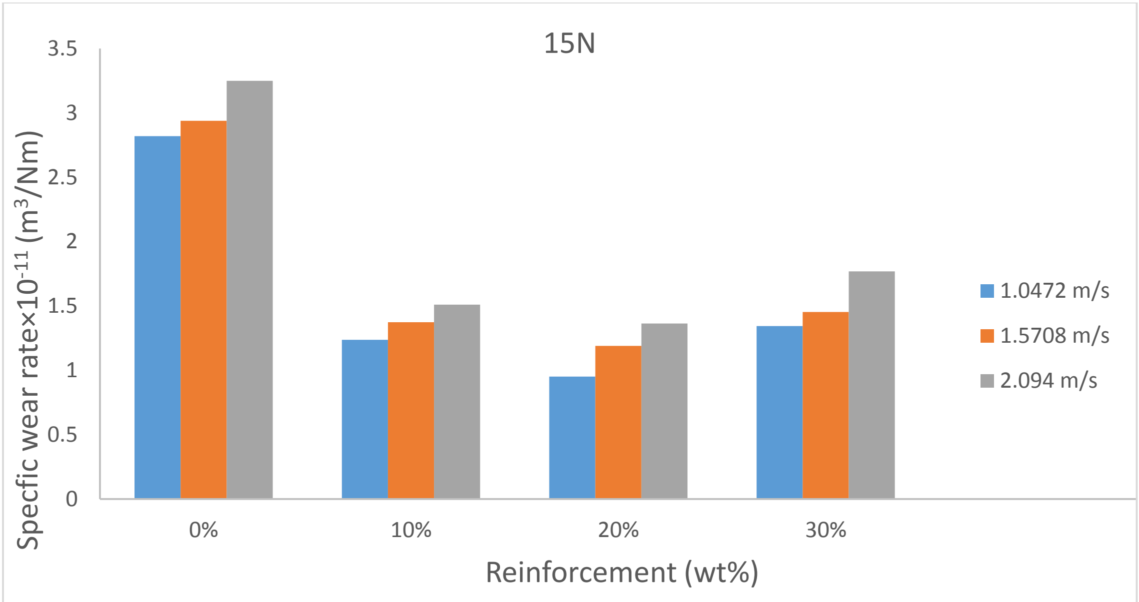


Figure-4.24 (Specific wear rate with weight fraction for Orange peel epoxy composite at 15 N)

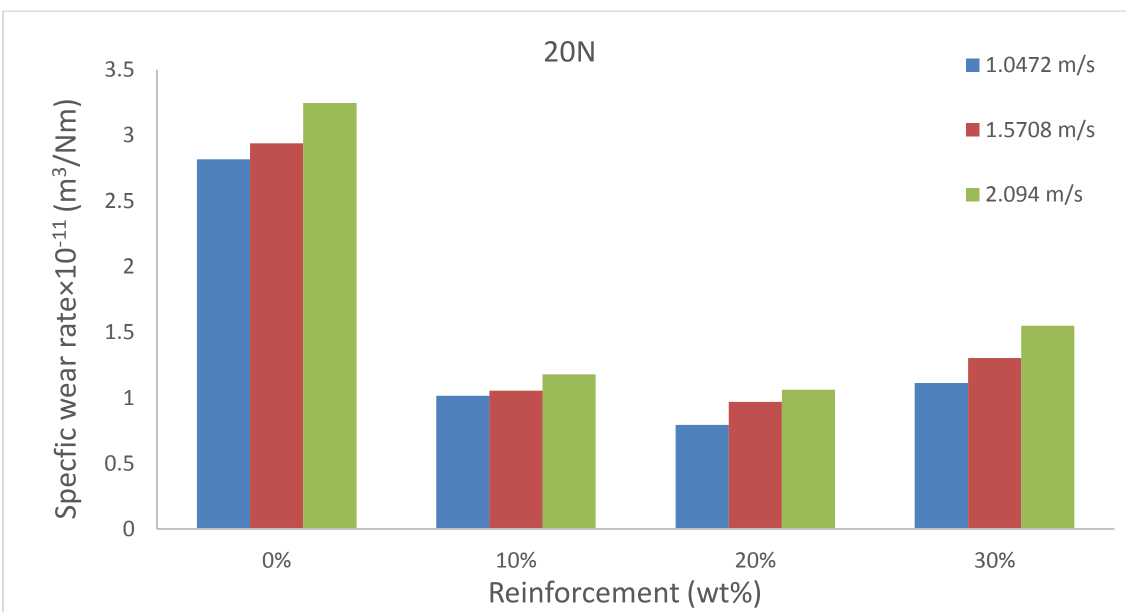


Figure-4.25 (Specific wear rate with weight fraction for Orange peel epoxy composite at 20 N)

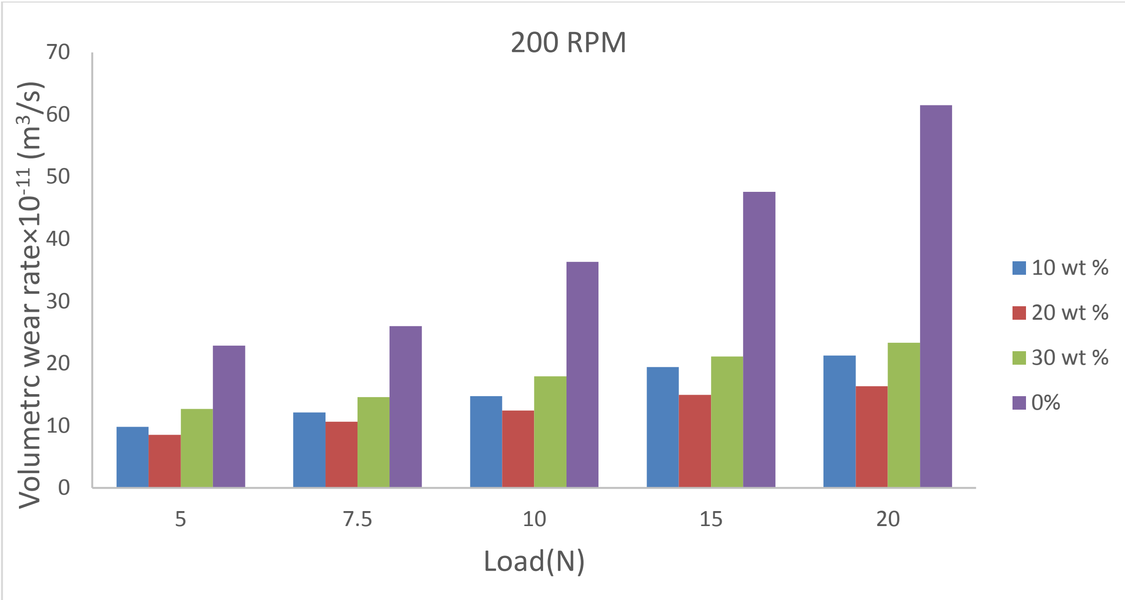


Figure-4.26(Volumetric wear rate with load for Orange peel epoxy composite at 1.047 m/sec)

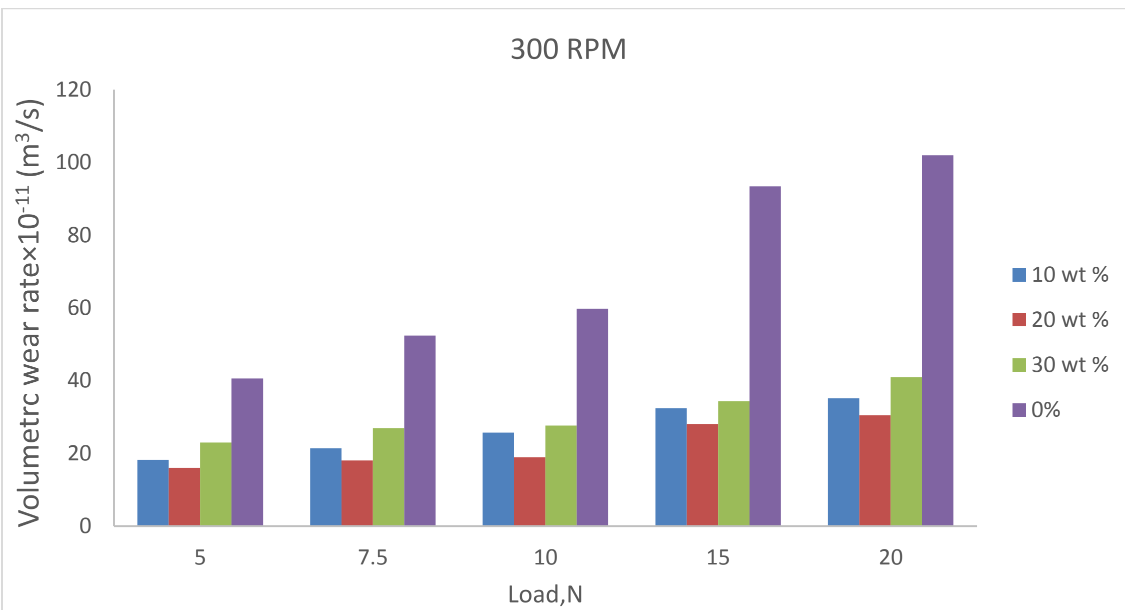


Figure4.-27(Volumetric wear rate with load for Orange peel epoxy composite at 1.571 m/sec)

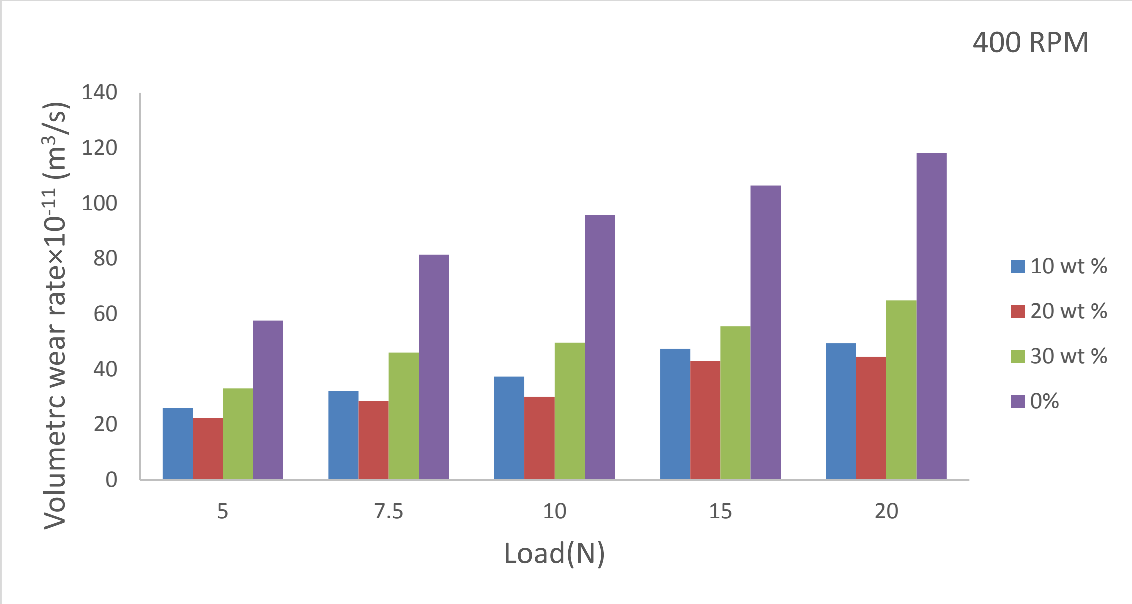


Figure-4.28(Volumetric wear rate with load for Orange peel epoxy composite at 2.094 m/sec)

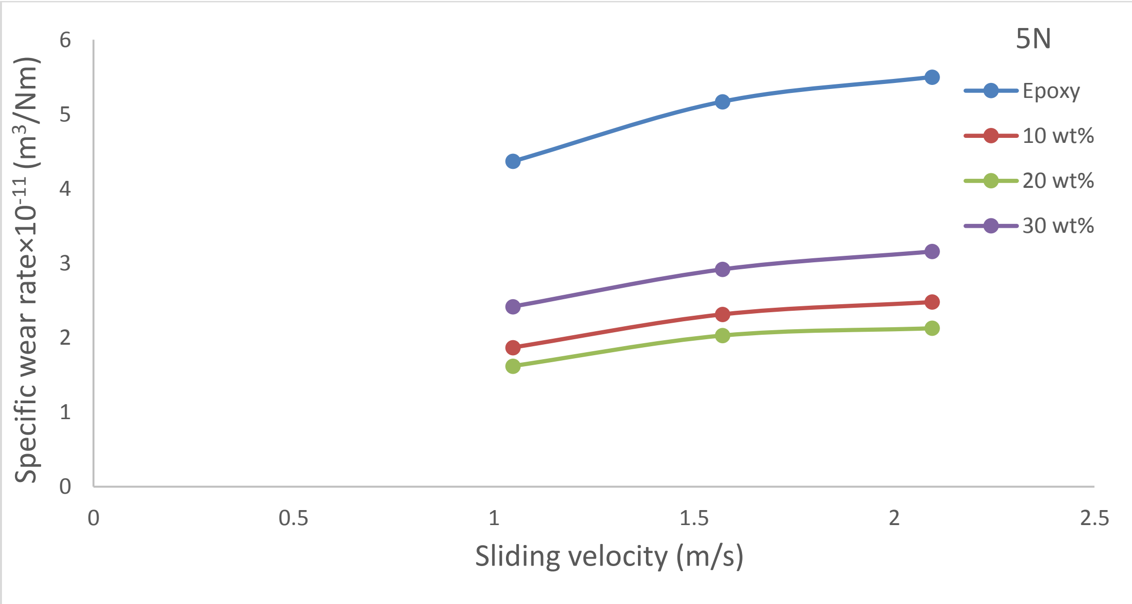


Figure-4.29 (Specific wear rate with sliding velocity for orange peel epoxy composite at 5 N)

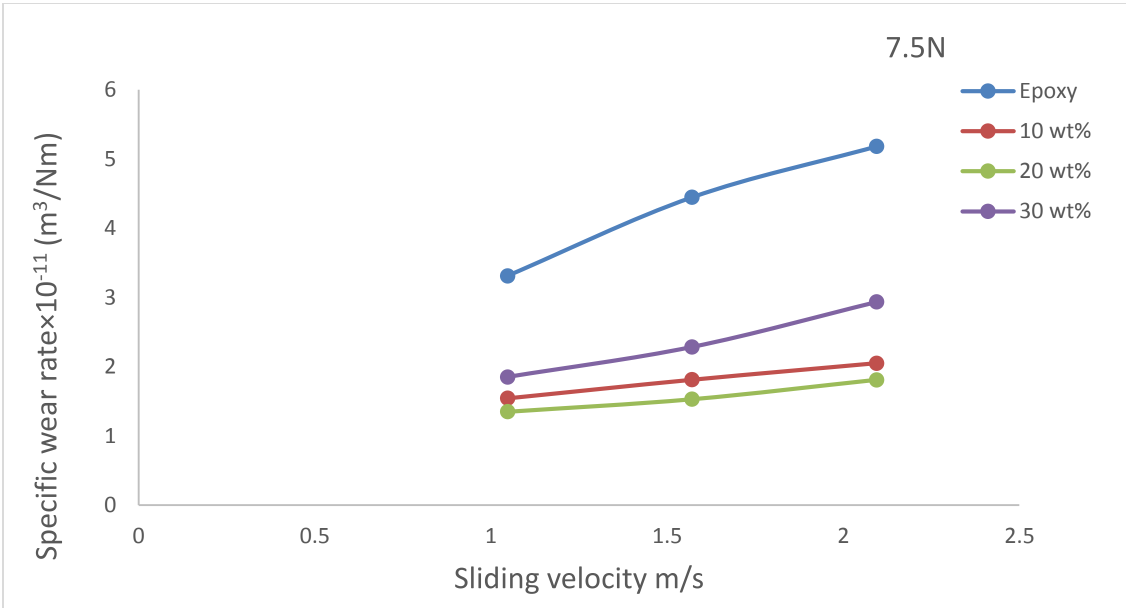


Figure-4.30 (Specific wear rate with sliding velocity for orange peel epoxy composite at 7.5 N)

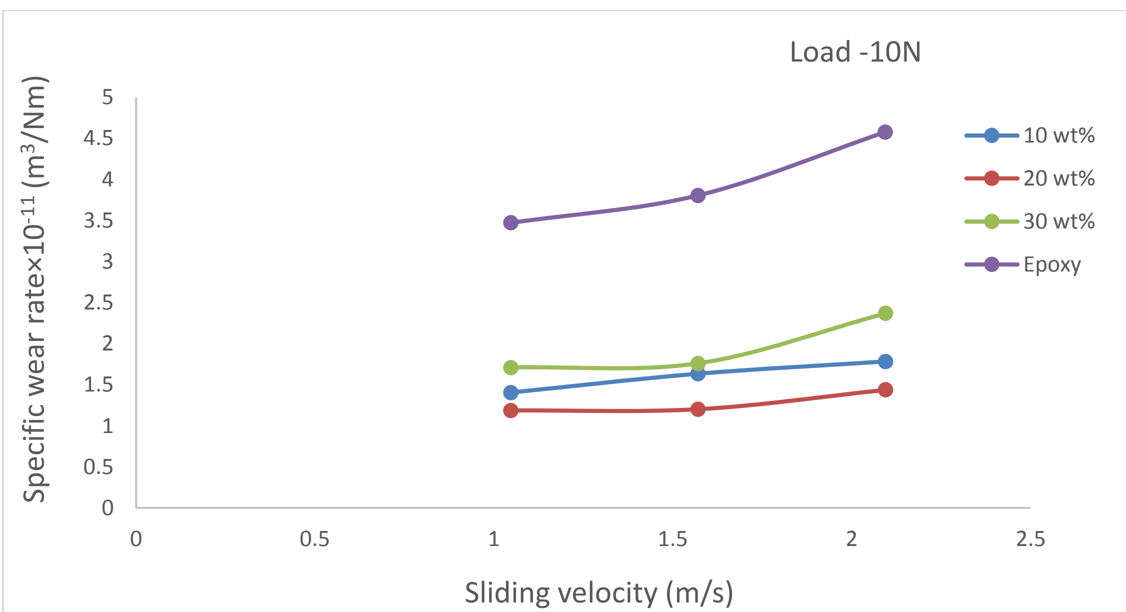


Figure-4.31 (Specific wear rate with sliding velocity for orange peel epoxy composite at 10 N)

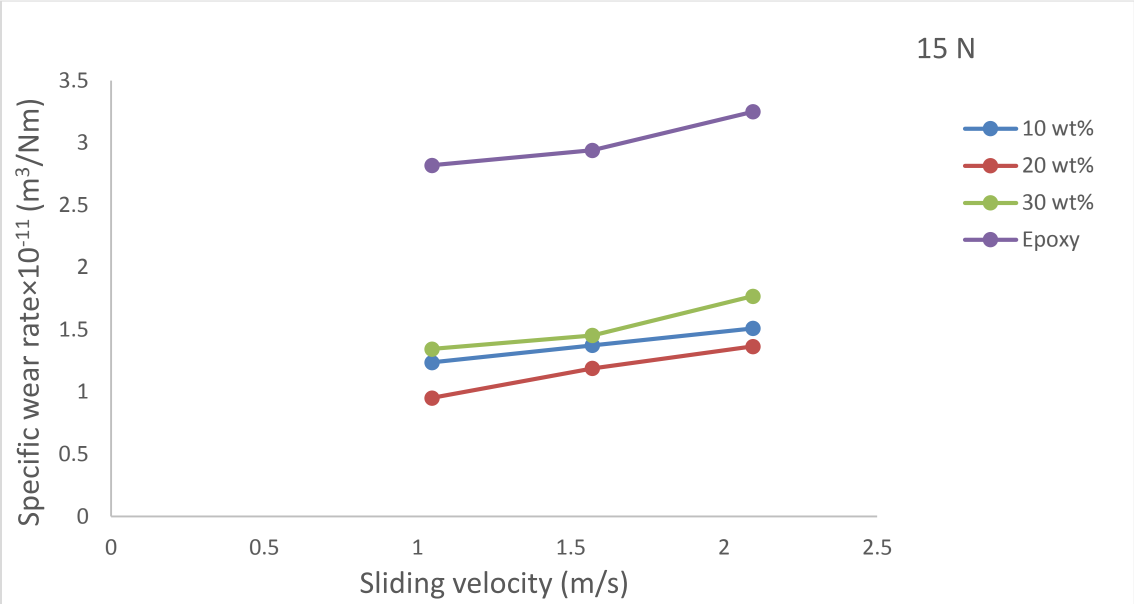


Figure- 4.32 (Specific wear rate with sliding velocity for orange peel epoxy composite at 15 N)

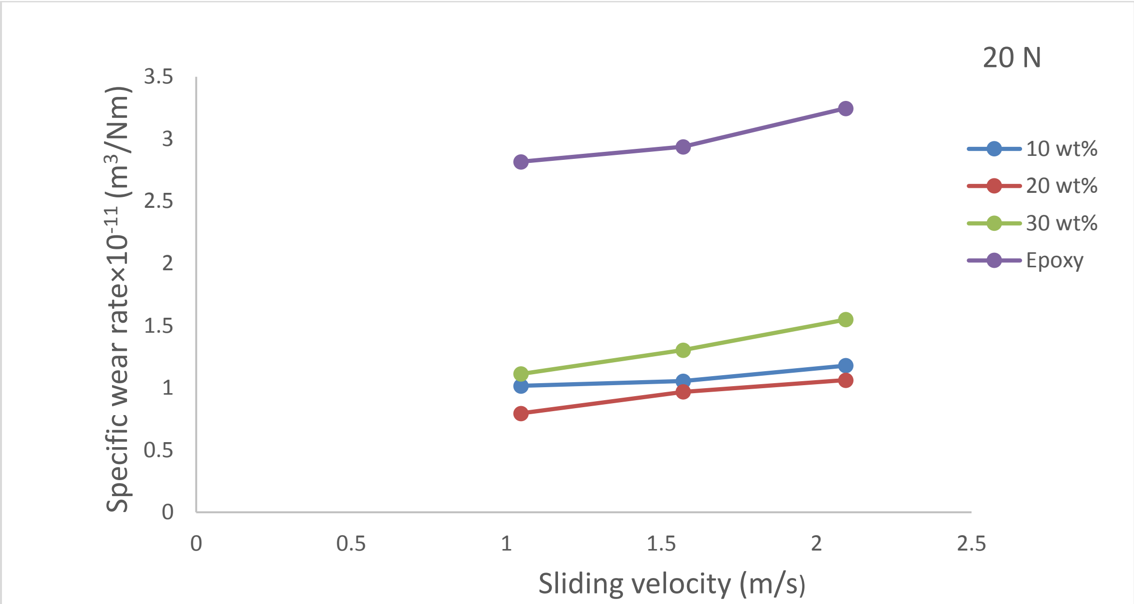


Figure-4.33 (Specific wear rate with sliding velocity for orange peel epoxy composite at 20 N)

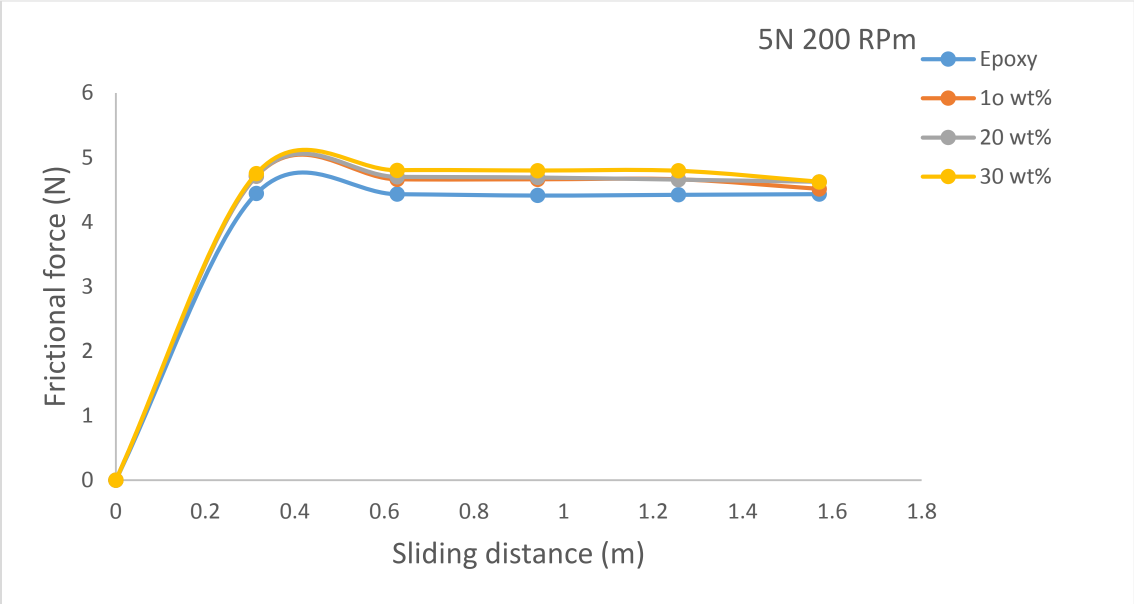


Figure-4.34(Frictional force with sliding distance for orange peel epoxy composite of different weight fraction)

Graphs are plotted and presented in the figure from (4.4-4.34) considering different test conditions and using different weight percentage of reinforcements(orange peels).Variation of wear rate with respect to sliding distance at a different sliding velocity of 1.0471 m/s (200RPM),1.5708 m/s (300RPM) and 2.0944 m/s (400RPM) using different loads (5.7.5,10,15 &20) is represented in the figure (4.6) to (4.12). It has been observed from the above figure, the wear rate decreases by reinforcing the orange peel fibers. From the above figure it is also observed that by increasing the sliding distance(increasing the RPM), the wear rate decreses for the all the test specimens. Also it has been obseved that for all the sliding distance the wear rate is more at the intial stage and gradually comes to a steady state. The reason behind for the above statement that there is a less penetration of abrasive particle into the composites so that there is less removal of material at the longer sliding distance. At the initial stage the abrasive paper used for the experiment is new and then becomes smooth by filling of the space by wear fragments. From the figure it is clearly observed that the wear rate is minimum for the 20 wt% orange peel fiber reinforced composites for all test conditons. The wear rate increases for higher wt fraction may be due to inadequate soaking of fiber or accumulation of fiber within the matrix which leads the poor interfacial adhesion between fiber and matrix.

The deviation of volumetric wear rate with changed loads for different wt. percentage of composites (0, 10, 20, 30) at different velocities is represented in the figure 4.26, 4.27 and 4.28. It can be observed from the graph that the wear rate is maximum for pure epoxy or zero percentage reinforcement. It also observed that with increasing the normal load from 5N to 20 N the volumetric wear rate increases for all test samples irrespective of the sliding velocity. The reason behind is that at higher load the frictional force increases so that on the surface of the sample the fracture and deboning arises. The same result got by Cirino [33] taking carbon epoxy composite. Deo, Acharya [34] and Mishra, Acharya also got the same result by taking Lantana Camara and Bagasse fiber reinforced composite. The volumetric wear rate is normally low at 5N due to lower penetration and the less number of abrasive particle is in contact with the rubbing surfaces. Since most of the abrasive particles is in contact at the higher load, so abrasion wear was increased greatly and generates extra grooves.

The figures from (f4.21-4.25) shows the variation of specific wear rate of different wt. percentage of composites with different velocities at varying load conditions. It is cleared that the specific wear rate of the reinforced composite increases with increasing the sliding velocity .For 30 wt. fraction of the filler it is observed that that the wear rate increases to a very high value in comparison to other wt. fractions. This result can also be related to the results projected in the figure (18-31).

The variation of friction coefficient for orange peel reinforced epoxy composite with varying load for different sliding velocity has shown in figure. It has been observed that by increasing the load the friction coefficient decreases. Reduction is also noticed by adding the reinforcement. The 20 wt. % shows the minimum coefficient of friction whereas zero wt. percentage (epoxy) shows the maximum.

From the above discussion it is clearly mention that the addition of orange peels into epoxy improves the tribological performance. A similar result was reported by Samantarai [35] by taking rice husk reinforced polymer composite.

Chapter-5

CONCLUSION & FUTURE WORK

The following conclusions are drawn from the present work:

1. The Orange peel can efficiently be used as reinforcing agent to prepare the composite for the better products by suitable bonding with resin.
2. Use of orange peel as reinforcing agent can reduce the wear loss. The optimal wear resistance of orange peel epoxy composite was obtained for 20 percent wt. fraction.
3. The wear rate steadily falls and attains a stable state with increasing the sliding distance.
4. The specific wear rate decreases with incorporation of orange peel fiber. In this present study the maximum wear resistance to the composite is found at 30 percent wt. fraction.
5. The better tensile strength and flexural strength was given by 20 wt. percent orange peel epoxy composites.

Recommendation for future work:

1. Hand- lay- up method is used in the present study to fabricate the composite. The other manufacturing processes are also there for manufacturing the polymer matrix composite. Taking this result as the base result final conclusions can be drawn by manufacturing the composite by other methods.
2. In this test the abrasive paper used is 400 grit size, the similar experiment may be conducted for other size paper.

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